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* The names in this list are those of the foreign members elected before February, 1880, at which time (see Proceedings of the New York Meeting, *Transactions*, vol. viii., p. 281) Rules I., II. and V. were so amended as to abolish the distinctive class of foreign members, as previously existing. All foreign members elected since that date are included in the general list of "Members and Associates" on page viii.

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OCTOBER, 1884.

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*GRISCOM, SAMUEL E., ... 324 N. Eighth Street, Philadelphia.
*GRISWOLD, CHESTER, ... 56 Broadway, New York City.
*GRISWOLD, FRANCIS B., ... Troy, N. Y.
*GRISWOLD, J. WOOL, ... Troy, N. Y.
*GRITTINGER, HENRY C, ... Cornwall, Lebanon Co., Pa.
*GROESBECK, J. D, ... P. O. Box 96, Tombstone, Arizona.
*GROSS, HENRY S, ... 119 Market Street, Harrisburg, Pa.
*GROVE, JOHN H., ... Danville, Pa.
*GURLEY, WILLIAM, ... Troy, N. Y.

*HABERSHAW, W. M., ... 159 Front Street, New York City.
*HACKETT, WILLIAM H., ... 226 Marietta Street, Atlanta, Ga.
*HACKNEY, HERBERT, ... Portland, Oregon.
†HADLEY, WALTER C., ... Las Vegas, N. M.
*HAGERMAN, J. J., ... 86 Michigan Street, Milwaukee, Wis.
*HAGUE ARNOLD, ... University Club, New York City.
*HAHN, IGNATIUS, . . . P. O. Box 155, Sharpsburg, Allegheny Co., Pa.
*HAHN, O. H., ... P. O Box 8, South Pueblo, Colorado.
*HAINES, REUBEN, . Wayne Street below Queen, Germantown, Philadelphia.
*HALBERSTADT, BAIRD, ... Pottsville, Pa.
*HALE, PROF. ALBERT C, ... P. O. Box 65, Brooklyn, N. Y.
*HALE, ALBERT W., ... 71 Broadway, New York City.
*HALL, C. C., ... 313 Iron Street, S. St. Louis, Mo.
*HALL, EDWARD J., JR., ... 80 Astor House, New York City.
*HALL, HENRY J., ... Palace Hotel, San Francisco, Cal.
*HALL, ROBERT W., ... 3 W. Fifty-sixth Street, New York City.
*HALSEY, FRED A., ... 23 Park Place, New York City.
*HALSEY, WILLIAM S., Care of F. M. Davis, Eighth & Larimer Sts., Denver, Col.
*HAMILTON, ALEXANDER, ... Drawer PP., Johnstown, Pa.
*HAMILTON, WILLIAM G., ... 24 West Street, New York City.
*HAMMOND, CHARLES L., ... Crown Point, Essex Co., N. Y.
*HAMMOND, JOHN HAYS, ... 56 Wall Street, New York City.
*HAMMOND, W. B, ... Deadwood, Dakota.
*HARDEN, E. B., ... 537 N. Thirty-third Street, Philadelphia.
*HARDEN, J. H, ... Phœnixville, Pa.
*HARDEN, O. B., ... 1915 N. Twentieth Street, Philadelphia.
*HARDMAN, JOHN E, ... P. O. Box 396, Lowell, Mass.
*HARE, A. W., ... Cañon City, Colorado.
*HARKER, O. H., ... Leadville, Colorado.
*HARNICKELL, A., ... P. O. Box 2503, New York City.
*HARRINGTON, DR. B J., ... McGill College, Montreal, Canada.
*HARRIS, JOSEPH S., ... 226 S. Third Street, Philadelphia.
*HARRIS, O. D., ... Ste. Genevieve, Mo.
*HARRIS, W. J., ... 18 Broadway, New York City.
*HARRISON, EDWIN, ... 322 Pine Street, St. Louis, Mo.
*HARRISON, RUSSELL B., Superintendent U. S. Assay Office, Helena, Montana.
*HART, PROF. EDWARD, ... Lafayette College, Easton, Pa.
†HART, WILLIAM R., ... 224 S. Third Street, Philadelphia.

*Hartman, John M., ... 1235 N. Front Street, Philadelphia.
*Hartranft, S. S., ... 2015 Spruce Street, Philadelphia.
*Hartshorne, J., ... P. O. Box 736, Johnstown, Pa.
*Harty, William, ... P. O. Box 207, Portsmouth, Ohio.
†Harvey, William H., . . Commonwealth Iron Co., Cleveland, Ohio.
*Hastings, Robert E., ... 819 Filbert Street, Philadelphia.
*Hausling, F. M., ... Tin Cup, Gunnison Co, Colorado
*Haws, H. Y., ... Johnstown, Pa.
*Hayden, Dr. F. V., ... 1803 Arch Street, Philadelphia.
*Hayden, W. B., ... Columbus, Ohio.
*Haydon, J. C., ... Jeansville, Luzerne Co., Pa
*Heard, John, ... Care J. M. Ortiz y h^{os}, Alamos, Sonora, Mexico.
*Hearne, Frank J., ... Wheeling, West Va.
*Heartt, Jonas S, ... Troy, N. Y.
*Heckscher, A, ... 212 Walnut Street, Philadelphia.
*Hegeler, Edward C., ... La Salle, Ill.
*Heinrich, Oswald J., ... Drifton, Luzerne Co, Pa.
*Hemenway, E. P., ... Cambria Iron Co., Johnstown, Pa.
*Hemphill, James, ... Twelfth and Pike Streets, Pittsburgh, Pa.
*Henderson, C. Hanford, ... 201 S. Fifth Street, Philadelphia.
*Henrich, Carl, ... Clifton, Arizona.
*Herndon, Edward L, ... 210 N. Third Street, St. Louis, Mo.
*Herr, H. B., ... U. S. Engineers' Office, Chicago, Ill.
*Herrick, J. A., ... P. O. Box 2829, New York City.
*Herrick, J. T., ... Fairplay, Park Co., Colorado.
*Hewett, G. C., ... Winifrede, Kanawha Co., W. Va.
*Hewitt, Abram S., ... 17 Burling Slip, New York City.
*Hewitt, George H., ... 2 Wall Street, New York City.
†Hexamer, C. John, ... 419 Walnut Street, Philadelphia.
†Heywood, George H., ... Gardner, Mass.
*Hibbard, Henry D., ... Norway Iron Co., S. Boston, Mass.
*Hibbs, James M., ... 1330 Buttonwood Street, Philadelphia.
†Hickox, Charles V., ... 175 Dearborn Street, Chicago, Ill.
†Hildreth, Walter E., ... 52 Broadway, New York City.
*Hill, Albert F., ... 83 Reade Street, New York City.
*Hill, Frank A., ... P. O. Box 501, Scranton, Pa.
*Hill, Leslie C., ... Helena, Montana.
*Hillman, John H., ... Hematite, Trigg Co., Ky.
*Hills, William R., ... Albany, N. Y.
*Hinchman, Charles S., ... 208 S. Fourth Street, Philadelphia.
*Hitchcock, Prof. C. H., ... State Geologist, Hanover, N. H.
*Hitchcock, E. A., ... St. Louis Ore and Steel Co., St. Louis, Mo.
*Hoatson, Thomas, ... Calumet, Michigan.
*Hodges, A. D., Jr., ... 39 St. James Street, Roxbury, Mass.
*Hoffman, E. O., ... Lock Box 1208, Pullman, Ill.
*Hoffman, John W., ... 208 S. Fourth Street, Philadelphia.
*Hoffmann, Ottokar, Corner Fifth and Bryant Streets, San Francisco, Cal.
*Hofman, H. O., ... Argentine, Kansas.
*Hoffstott, F. N., ... P. O. Box 177, Pittsburgh, Pa.
*Holbrook, F. N., ... El Paso, Texas.
†Holbrook, Levi, ... P. O. Box 536, New York City.

*Hollenbeck, J. I., ... Audenried, Carbon Co., Pa.
*Hollerith, Herman, . . . 617 Seventh Street, Washington, D. C.
*Holloway, J. F., . . . Detroit and Center Streets, Cleveland, Ohio.
*Holman, F. C., ... Santa Rosa, Cal.
†Holt, George H., ... Crested Butte, Gunnison Co., Colorado.
*Hooker, W. A., ... 2 Wall Street, New York City.
*Hooper, William, ... Ticonderoga, N. Y.
*Horton, N. W., ... 23 Park Place, New York City.
*Hotchkiss, Jed., ... Staunton, Va.
*Houghteling, James L., ... 244 S. Water Street, Chicago, Ill.
*Houston, C. B., ... Thurlow, Delaware Co., Pa.
*Houston, T. J., ... Thurlow, Delaware Co., Pa.
*Howald, Ferdinand, ... Fire Creek, Fayette Co , W. Va.
*Howe, Frank P., ... Danville, Pa.
*Howe, Henry G., ... P. O. Box 196, Tombstone, Arizona.
*Howe, Henry M , ... 75 State Street, Boston, Mass.
*Howell, Benjamin P., ... Scottdale, Pa.
*Huber, H., ... Socorro, N. M.
*Hulbert, Edwin J., ... Middletown, Conn.
†Hulbert, Thomas H., ... Middletown, Conn.
†Hulick, William H., ... Easton, Pa.
*Hulst, Nelson P., ... 300 Knapp Street, Milwaukee, Wis.
†Humbert, William S., ... 7 Nassau Street, New York City.
*Humphrey, D. W., ... 524 Quincy Avenue, Scranton, Pa.
*Humphrey, George S., ... Oxford, N. J.
*Humphreys, A. W., ... 42 Pine Street, New York City.
*Hungerford, W. S., ... Low Moor, Va.
†Hunicke, Aug., ... 806 Olive Street, St. Louis, Mo.
*Hunt, Alfred E., ... 98 Fourth Avenue, Pittsburgh, Pa.
*Hunt, Fred. F., ... P. O. Box 335, Quebec, Canada.
*Hunt, Joseph, ... Catasauqua, Pa.
*Hunt, Joshua, ... Catasauqua, Pa.
*Hunt, Robert W., . Albany and Rensselaer Iron and Steel Co., Troy, N. Y.
*Hunt, Dr. T. Sterry, ... Montreal, Canada.
*Hutchinson, E. S., ... Newtown, Pa.
*Hutchinson, William S., ... 79 Dearborn Street, Chicago, Ill.
*Hutter, E. S., ... Brugh's Mill, Botetourt Co., Va.
*Hutton, Fred. R., ... 6 W. Thirty-third Street, New York City.
*Hutton, William R., ... 35 Broadway, New York City.

*Ihlseng, Axel O., ... Golden, Colorado.
*Ingersoll, S. Warren, ... 227 S. Fourth Street, Philadelphia.
†Ingham, William A., ... 320 Walnut Street, Philadelphia.
*Inman, Alvin L., ... Crown Point, Essex Co., N. Y.
*Irving, Prof. Roland D., ... University of Wisconsin, Madison, Wis.
*Irving, William, ... Chicago Club, Chicago, Ill.
†Irwin, John H., ... Morton, Delaware Co., Pa.

*Jackson, Edward F., ... 3706 Washington Avenue, St. Louis, Mo.
*James, Isaac E., ... Duncan, Arizona.
*James, Reese, ... South Pueblo, Colorado.

*James, Samuel, Jr., ... Cooke City, Montana.
*James, Thomas, ... Braddock, Pa.
†James, Dr. Walter M., ... 1123 Spruce Street, Philadelphia, Pa.
†James, William, ... St James, Phelps Co., Mo.
*Jamme, George, ... Londonderry, Nova Scotia.
*Janin, Henry, ... 12 Fifth Avenue, New York City.
*Janin, Louis, ... 310 Pine Street, San Francisco, Cal.
*Janney, Morris P., ... Pottstown, Pa.
†Jarvis, W. F., ... 34 Campan Building, Detroit, Mich.
*Jenney, Walter P., ... P.O. Box 651, Salt Lake City, Utah.
*Jennings, E P., ... Sterlington, Rockland Co., N. Y.
*Jennings, Hennen, ... Quicksilver Mining Co, New Almaden, Cal.
*Jennings, W. H., ... C. H. V. & T. Railway, Columbus, O
*Jeter, J. Tinsley, ... Wilkesbarre, Pa.
*Jewell, Edward E., . North Chicago Rolling Mill Co, S Chicago, Ill.
*Jewett, Eliot C., ... U. S. Assay Office, St. Louis, Mo.
*Johnson, Lieut. D. D., ... Fort Monroe, Va.
*Johnson, Isaac G., ... Spuyten Duyvil, New York City.
*Johnson, J. E., ... Longdale, Alleghany Co., Va.
*Johnson, W. G., ... Pine Grove, Pa.
*Johnston, Walter N., ... Buchanan, Botetourt Co., Va.
*Jolliffe, William, ... Lexington, Va.
*Jones, B. F., ... American Iron Works, Pittsburgh, Pa.
*Jones, D. N., ... Colorado Coal and Iron Co., Bessemer, Colorado.
*Jones, Griffith, ... Pottstown, Pa.
*Jones, John T., ... Quinnesec, Menominee Co., Mich.
*Jones, R. R, ... Union Iron and Steel Co., Chicago, Ill.
*Jones, T. Catesby, ... Richmond, Va.
*Jones, Thomas D., ... Ebervale, Pa.
†Jones, Thomas D., ... 33 Portland Block, Chicago, Ill.
*Jones, W. R., ... Braddock, Pa.
*Jones, Washington, ... 1632 N. Fifteenth Street, Philadelphia.
*Jopling, Jas. E., ... Marquette, Mich.
*Jouet, C. H., ... Roselle, N. J.
†Julian, Frank, ... Iron Mountain, Menominee Co., Mich.

*Kaercher, Edw. E., ... Shamokin, Pa.
*Kaufman, William M., ... Reading, Pa.
*Kay, Prof. Edgar B., ... 153 Eighth Street, Troy, N. Y.
*Kean, John, Jr., ... Elizabeth, N. J.
*Kearney, Henry S., ... P. O. Box 338, Leadville, Colorado.
*Kebler, Eliot A., ... Newport, Ky.
*Keeley, Jerome, ... 206 Walnut Place, Philadelphia.
*Keen, Barton L., ... Springfield Iron Co., Springfield, Ill.
†Keith, H. A., ... Chicago, Ill.
*Keith, N. S., ... 9 Murray Street, New York City.
*Keller, Arthur H., ... P. O. Box 48, Silverton, Colorado.
*Keller, Hermann A., ... P. O. Box 267, Leadville, Colorado.
*Kemp, William, ... Troy, N. Y.
*Kempton, C. W., ... 61 Broadway, New York City.
*Kennedy, Hugh, ... Etna, Allegheny Co., Pa.
*Kennedy, John, ... Montreal, Canada.

*Kennedy, John S., ... Lock Box 5, Steelton, Dauphin Co., Pa.
*Kennedy, Julian, ... Braddock, Allegheny Co., Pa.
*Kent, Joseph C., ... Phillipsburg, N. J.
*Kent, R., ... Standard Steel Works, Lewistown, Pa.
*Kent, William St. G., ... Phœnixvillle, Pa.
*Kent, William, . Babcock & Wilcox Co., 30 Cortlandt Street, New York City.
†Kerr, Thomas B., ... 110 Diamond Street, Pittsburgh, Pa.
*Kerr, Prof. W. C., ... Raleigh, N C.
*Keyes, W. S., ... P. O. Box 1716, San Francisco, Cal.
*Kiddie, Thomas, . . . P. O. Box 44, New Brighton, Staten Island, N. Y.
*Kimball, Hiram, ... City Forge, Cleveland, Ohio.
*Kimball, Dr. J. P., ... Lehigh University, Bethlehem, Pa.
*Kinealy, James R., ... Baden, St Louis City, Mo.
*King, Charles F., ... Steelton, Dauphin Co., Pa.
*King, Daniel, ... ,Pine Grove Furnace, Cumberland Co., Pa.
*King, Frank, ... Van Buren Furnace, Shenandoah Co., Va.
†King, J. H., ... Painesville, Lake Co., Ohio.
*King, Thomas M., ... B. & O. R. R., Pittsburgh, Pa.
*Kingsley, J. Cook, ... P. O. Box 48, Silverton, Colorado.
*Kinkead, Max, ... Altoona, Pa.
Kirby, Edmund B., . . . Oregon Avenue and Juniata Street, St Louis, Mo.
*Kirchhoff, Charles, Jr., ... 369 Union Street, Brooklyn, N. Y.
*Klepetko, Frank, ... Opechee, Houghton Co., Mich.
*Knap, Charles, ... 1730 H Street, Washington, D. C.
*Knap, Charles, Jr., ... Richardsville, Culpeper Co., Va.
*Knap, James G., ... Ogdensburgh, N. Y.
*Knap, Joseph M., ... 365 West Street, New York City.
*Knight, Albert B., ... Virginia City, Montana.
*Knight, E., ... Troy, N. Y.
*Knorr, A. E., ... U. S. Dept. of Agriculture, Washington, D. C.
*Knox, John H., ... Lebanon, Hunterdon Co., N. J.
*Koenig, Prof. George A., . University of Pennsylvania, W. Philadelphia.
*Koerner, F., ... Deloro, Ontario, Canada.
*Kramer, Frank J., ... Parryville, Carbon Co., Pa.
*Kriete, Henry C., ... 17 Metropolitan Block, Chicago, Ill.
*Kunhardt, Wheaton B., ... 32 Beaver Street, New York City.

*Lagerfelt, C. O., ... 15 Cortlandt Street, New York City.
†Lamberton, William B., ... 216 Market Street, Harrisburg, Pa.
*Lamborn, Dr. Robert H., ... 47 William Street, New York City.
*Lane, J. S., ... Akron, Ohio.
*Landis, Edward K., ... Pottstown, Pa.
*Landsberg, E., ... Aachen, Germany.
*Langdon, N. M., ... Chester, Morris Co., N. J.
*Lathrop, W. A., ... Snowshoe, Center Co., Pa.
*Lauder, George, ... Larimer's Station, Westmoreland Co., Pa.
*Laureau, L. G., ... 16 Exchange Place, New York City.
*Lauth, B. C., ... First National Bank, South Side, Pittsburgh, Pa.
*Lawrence, Benjamin B., ... Montezuma, Summit Co., Colorado.
*Lawrence, W. L., ... Burden, Columbia Co., N. Y.
†Leary, Daniel J., ... 138 Keap Street, Brooklyn, N. Y.
*Leavitt, E. D., Jr., ... 604 Main Street, Cambridgeport, Mass.

*Leavitt, W. A., ... 2032 N. Twenty-second Street, Philadelphia.
†Le Baron, J Francis, ... Jacksonville, Fla.
*Leckie, Robert G., ... Sherbrooke, Quebec, Canada.
*Lee, R. H, ... Lewistown, Pa.
*Lee, R H., Jr, ... Lewistown, Pa.
*Lee, Richard Henry, ... Duluth, Minn.
*Leggett, Thomas H., ... Flushing, L I., N. Y.
*Lehman, A. E., ... 711 Walnut Street, Philadelphia.
†Lehman, F. L., ... 99 John Street, New York City
*Leisenring, E. B., ... Mauch Chunk, Carbon Co , Pa.
*Leith, Alexander J., ... Honoré Building, Chicago, Ill.
*Lennig, Nicholas, ... 112 S. Front Street, Philadelphia.
*Leonhard, Alexander von, ... Berlin, Germany.
*Lesley, Prof. J. P., . . State Geologist, 1008 Clinton Street, Philadelphia.
*Lewis, David B., ... Palatka, Florida.
*Lewis, James B., ... Dover, N. J.
*Lewis, James F., ... 401 E. Franklin Street, Richmond, Va.
*Lewis, John C, ... 22 Cortlandt Street, New York City.
†Lewis, Samuel W., ... 55 Broadwav, New York City.
*Lilienberg, N., ... 150 Broadway, New York City.
*Lilly, William, ... Mauch Chunk, Pa.
*Lincke, Gustav, ... Bromberg, Prussia.
*Lincoln, Charles J., ... English High School, Boston, Mass.
*Lincoln, G. Russell, ... P. O. Box 65, Harrisburg, Pa.
*Lindgren, Waldemar, ... Anaconda, Montana.
*Lindsley, Stuart, ... Orange, N. J.
*Little, Frank J., . . . North Chicago Rolling Mill Co., S. Chicago, Ill.
*Livingston, Herman, ... Catskill Station, Columbia Co., N. Y.
*Lobanoff, Paul F., ... 277 Lasalle Avenue, Chicago, Ill.
*Lodge, Richard W., . . North Chicago Rolling Mill Co, So. Chicago, Ill.
†Logan, John P., ... 319 Walnut Street, Philadelphia.
*Loiseau, E. F., ... 303 Walnut Street, Philadelphia.
*Loiseau, Oscar, ... Ougrée, Belgium.
*Long, John C., ... Mont Alto, Franklin Co., Pa.
*Long, William H., ... Fairlee, Vermont.
*Longacre, Orleans, ... 141 Centre Street, New York City.
*Longnecker, G. A., ... Mechanicsburg, Pa.
*Lord, Prof. N. W., ... Ohio State University, Columbus, Ohio.
*Lord, R. F., ... Georgetown, Colorado.
*Lorenz, William, ... 227 S. Fourth Street, Philadelphia.
*Lowe, Theodore H., ... Idaho Springs, Colorado.
†Luce, Edward M., ... Milwaukee, Wis.
†Ludlam, Joseph S., ... Lowell, Mass.
*Lukens, Jawood E., ... Conshohocken, Pa.
†Lunn, Maurice J., ... Lewis Block, Pittsburgh, Pa.
*Luther, Henry M., ... Ashland, Pa.
*Luther, R. C., ... Pottsville, Pa.
*Lyman, Benjamin Smith, ... Northampton, Mass.
†Lyman, Frank, ... 34 Remsen Street, Brooklyn, N. Y.

†McCallum, Wm. H., . New Glen Echo Mills, Wayne Junction, Philadelphia.
*McCandless, E. V., ... Pittsburgh, Pa.

*McClellan, Arthur, ... Drifton, Luzerne Co., Pa.
*McClure, Robert J., ... C B. & Q. R. R. Co., Chicago, Ill.
*McComb, A. M., . . . 55 E. Harrison Street, Frankford, Philadelphia.
*McCormick, Henry, ... Harrisburg, Pa.
*McCreath, Andrew S, ... 223 Market Street, Harrisburg, Pa.
*McCulloh, E. A., ... P. O Box 2346, New York City.
*McDermott, Walter, ... 2 Wall Street, New York City.
*McDowell, Frederick H, ... 120 Liberty Street, New York City.
†McDowell, Joseph J., . Rooms 1 and 2, Singer Building, St. Louis, Mo.
†McElmell, Thomas A., ... Krams Cañon, Apache Co., Arizona.
*McFadyen, John, ... Johnstown, Pa.
*McGinness, Major J. R., . . . Jefferson Barracks, St Louis Co, Mo.
*McGuffin, J. A., ... Sewell Depot, C. & O. Ry, Fayette Co., Va.
†McIntosh, William A., ... 41 Fifth Avenue, Pittsburgh, Pa.
†McKee, David, ... 9 Madison Avenue, Memphis, Tenn.
†McKenzie, Dr. John C., . . 328 Montgomery Street, San Francisco, Cal.
*McKeown, S W., ... Youngstown, Ohio.
*McLanahan, J. King, ... Hollidaysburg, Pa.
*McLeavy, John, ... Punxsutawney, Pa.
*McLeod, H. S., ... Troy, N. Y.
*McMillan, Prof. Chas., ... Princeton, N. J.
*McNair, Thomas S., ... Hazleton, Pa.
*Macdonald, Charles, ... 52 Wall Street, New York City.
*Mackintosh, James B., ... 55 Garden Street, Hoboken, N. J.
†Mackintosh, W. S., ... Foot of Twelfth Street, Pittsburgh, Pa.
*Macy, Arthur, ... Silver King, Arizona.
*Maffet, W. R., ... Wilkes-Barre, Pa.
*Mahon, Prof. R. W., ... Lafayette College, Easton, Pa.
*Male, John, ... Troy, N. Y.
*Mann, H. F., ... P. O. Box 1028, Pittsburgh, Pa.
*Manning, Thomas, ... 53 Beaver Street, New York City.
*March, William J., ... Ribon & March, Jersey City, N. J.
*Markham, Alfred, ... Markhamville, N. B., Canada.
*Markle, John, ... Jeddo, Luzerne Co., Pa.
*Marple, William M., ... Bridgeport, Montgomery Co., Pa.
*Mars, John H., ... Albany, N. Y.
*Marshall, Benjamin, ... Sandusky, Ohio.
*Marshall, Charles A., ... P. O. Box 766, Johnstown, Pa.
*Martin, E. P., ... Dowlais, Glamorgan, Wales.
*Martin, R L., ... Fairchance, Fayette Co., Pa.
*Martine, Charles A., ... Georgetown, Colorado.
*Martyn, William, ... 18 Brighton Street, Charlestown, Mass.
*Marvin, Selden E., ... Albany, N. Y.
*Mason, Prof. William P., ... Troy, N. Y.
†Massie, Frank A., ... Vesuvius, Va.
*Masters, W. U., ... Cleveland, Ohio.
*Mather, Samuel, ... 101½ Water Street, Cleveland, Ohio.
*Mathieu, Jean A., ... 51 Moffat Block, Detroit, Mich.
*Mathis, T. S., ... Telluride, Colorado.
*Mattes, W. F., ... Scranton, Pa.
*Matthiessen, F. W., ... Lasalle, Ill.
*Maury, M. F., ... Avondale, Cincinnati, Ohio.

*Maury, S. Price, ... Richmond, Va.
*Maxon, John H., ... 2305 Washington Avenue, St. Louis, Mo.
*Maxson, Prof G. W., ... Auburn, Alabama.
*Maxwell, J. R., ... Hamilton, Ohio.
*Maxwell, J. W., ... 46 Kellogg Street, Syracuse, N. Y.
*May, De Courcey, . . Care of I. P. Morris & Co., Limited, Philadelphia.
*May, William A., ... Lock Box 173, Scranton, Pa.
*Maynard, George W, ... 35 Broadway, New York City.
*Mayo, James H., ... 164 Brattle Street, Cambridge, Mass.
*Meade, Spencer, ... N. Central Railway Co, Elmira, N. Y.
†Means, Archibald, ... Peru, La Salle Co, Ill.
*Meier, John W., ... 102 N. Main Street, St. Louis, Mo.
†Meigs, Prof. John, ... Pottstown, Pa.
*Meily, James, ... Wilmington, Del.
*Meister, Herman, . . . 3013 Maramec Street, Station B, St. Louis, Mo.
*Mell, Prof. P. H, Jr., ... Auburn, Alabama.
*Mercur, Frederick, ... Wilkes-Barre, Pa.
*Merritt, William Hamilton, . . 34 St. George Street, Toronto, Canada.
†Merryweather, George, ... 94 Dearborn Street, Chicago, Ill.
*Metcalf, O., ... Verona Tool Works, Pittsburgh, Pa.
*Metcalf, William, ... Pittsburgh, Pa.
*Meyer, Carl, ... Limburg, a d. L., Germany.
*Michaelis, Capt. O. E., ... Frankford Arsenal, Philadelphia.
*Mickley, Edwin, ... Hokendauqua, Pa.
*Miles, Fred. P., ... Copake Iron Works, Columbia Co., N. Y.
†Miller, Charles W., ... 271 Quincy Street, Brooklyn, N. Y.
*Miller, Horace B., ... 96 Fulton Street, New York City.
*Miller, Reuben, ... Pittsburgh, Pa.
*Milliken, George F., ... Tucson, Arizona.
*Mills, Frank P., ... Crystal Falls, Marquette Co., Mich.
*Mills, James E., ... Quincy, Plumas Co, Cal.
*Milnes, William, Jr., ... Milnes, Page Co., Va.
*Moen, Philip W., ... Worcester, Mass.
*Moffat, E. S., ... Scranton, Pa.
*Monell, Joseph T., ... P. O. Box 49, Bonne Terre, Mo.
*Moore, Charles J., ... P. O. Box 1247, Leadville, Colorado.
*Moore, James, ... Sixteenth and Buttonwood Streets, Philadelphia.
*Moore, Lycurgus B., ... 96 Fulton Street, New York City.
*Moore, Philip N., ... Olympia, Bath Co., Ky.
*Moore, William, ... Denver Club, Denver, Colorado.
†Moore, William P., ... 172 Bank Street, Norfolk, Va.
*Morgan, Charles H., ... Worcester, Mass.
*Morgan, James, ... 2528 Sarah Street, Pittsburgh, Pa.
*Morgan, Joseph, Jr., ... Johnstown, Pa.
*Morgan, T. R., ... Alliance, Ohio.
*Morison, George S., ... 35 Wall Street, New York City.
*Morrell, T. T., ... Cambria Iron Co., Johnstown, Pa.
*Morris, Henry G., ... 209 S. Third Street, Philadelphia.
†Morris, Israel W., ... 238 S. Third Street, Philadelphia.
*Morris, S. Fisher, ... 415 S. Center Street, Pottsville, Pa.
*Morris, William H., ... 400 Chestnut Street, Philadelphia.
*Morse, H. G., ... Youngstown, Ohio.

*MORSE, JAY C., ... 101½ Water Street, Cleveland, Ohio.
†MORSE, PHILIP S., ... P O. Box 219, Pueblo, Colorado.
*MOSES, ALFRED J., ... School of Mines, New York City.
*MOSS, PROF. MILTON, . . Colorado School of Mines, Golden, Colorado.
*MOYER, HORACE, I., ... Eckley, Pa.
*MUDD, SEELEY W., ... 500 N. Jefferson Avenue, St Louis, Mo.
*MUHLENBERG, N H., ... Reading, Pa.
*MUNROE, PROF. HENRY S., . . . School of Mines, New York City.
*MUNSON, GEORGE C., ... Lock Box 1910, Denver, Colorado.
†MURDOCK, JAMES H., ... 175 Wood Street, Pittsburgh, Pa.
*MURRAY, GEORGE, ... Franeklyn, Utah.

*NASON, PROF. HENRY B., . . Rensselaer Polytechnic Institute, Troy, N. Y.
*NEFTEL, KNIGHT, ... 39 Broadway, New York City.
*NEILL, JAMES W., ... Mine La Motte, Madison Co., Mo.
*NEILL, WILLIAM L., ... Solvay Process Co., Syracuse, N. Y.
*NEILSON, JAMES, ... Youngstown, Ohio.
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*Raymond, R. W., ... P. O. Box 223, New York City.
†Reed, E., ... Windsor Hotel, Denver, Colorado.
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†Robinson, Theodore W., ... Institute of Technology, Boston, Mass.
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*Suppes, Max, ... Troy, N. Y.
†Swain, A E., ... 902 Prospect Street, Cleveland, Ohio.
*Swain, Prof. George F., ... Institute of Technology, Boston, Mass.
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*Walter, T. Frank, ... Mauch Chunk, Pa.
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*Warren, Walter P., ... Troy, N. Y.
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*Watts, David, ... 223 Market Street, Harrisburg, Pa.
†Watts, Ethelbert, ... 326 Walnut Street, Philadelphia.
*Weaver, V. W., ... Coplay, Lehigh Co., Pa.
*Webb, H. Walter, ... 37 Wall Street, New York City.
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*Weidman, Barge C., ... P. O. Box 175, S. Bethlehem, Pa.
*Weimer, P. L., ... Lebanon, Pa.
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*Wells, H. L., ... Sheffield Scientific School, New Haven, Conn.
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*Wheeler, H. A., ... Washington University, St. Louis, Mo.
*Wheeler, Moses D., . . . P. O. Box 231, Stapleton, Staten Island, N. Y.
*Wheeler, William D., ... U. S. Assay Office, Helena, Montana.
*Wheelock, Jerome, ... Worcester, Mass.
*Whinery, S., ... Somerset, Ky.
Whitaker, Thomas D., ... Cedar Grove, Frankford, Philadelphia.
*Whitcomb, George D., ... 206 Lasalle Street, Chicago, Ill.
*White, William, Jr., ... Braddock, Allegheny Co., Pa.
*Whiting, S. B., ... Pottsville, Pa.
†Whitman, James N., ... P. O. Box 380, Beverly, Mass.
†Whitney, Eli, Jr., ... Whitneyville Armory, New Haven, Conn.
*Wickes, George T., ... Bozeman, Montana.
*Wiestling, George B., ... Mont Alto, Franklin Co., Pa.
*Wight, Sidney B., ... 403 Jefferson Avenue, Detroit, Mich.

*Wiles, Edwin L., ... Springfield Iron Co., Springfield, Ill.
*Wiley, William H., ... 15 Astor Place, New York City.
*Wilhelm, A., ... P. O. Box 178, Harrisburg, Pa.
*Wilkes, John, ... Charlotte, N. C.
*Williams, Albert, Jr., ... Box 591, Washington, D. C.
*Williams, Ben, ... Bisbee, Arizona.
*Williams, David, ... 83 Reade Street, New York City.
*Williams, D. H., ... Homestead, Allegheny Co., Pa.
*Williams, Prof. Edward H, Jr., ... P. O. Box 463, Bethlehem, Pa.
*Williams, Frederick H., ... S. St. Louis, Mo.
*Williams, Prof. J. F, ... Troy, N. Y.
*Williams, Henry, ... Butte City, Montana.
*Williams, John J., ... 32 Merchants' Exchange, San Francisco, Cal.
*Williams, John T., . Forty-fourth Street and East River, New York City.
*Williams, Lewis, ... Bisbee, Arizona.
*Williams, Samuel T, . . . Care of Henry Disston & Sons, Philadelphia.
*Williams, W. E., ... Springfield Iron Co., Springfield, Ill.
*Wills, L. E, ... Weissport, Carbon Co, Pa.
*Wilson, Eugene B., ... Cross Creek Collieries, Drifton, Pa.
†Wilson, Henry C, ... U. S Engineer Office, Memphis, Tenn.
*Wilson, John A, ... 435 Chestnut Street, Philadelphia.
*Wilson, J Chester, ... 419 Walnut Street, Philadelphia.
*Wilson, John T., ... Wilson, Walker & Co, Pittsburgh, Pa.
*Wilson, Joseph M., ... P. O. Box 1989, Joliet, Ill.
*Wilson, N. R., ... P. O. Box 1217, Leadville, Colorado.
*Wilson, William A., ... Park City, Utah.
*Winslow, Arthur, ... P. O. Box 274, Raleigh, N. C.
†Wishon, Walter W., ... Colorado Springs, Colorado.
*Wister, Jones, ... 230 S. Fourth Street, Philadelphia.
*Witherbee, Frank S., ... Port Henry, Essex Co., N. Y.
*Witherbee, T. F., ... Port Henry, Essex Co., N. Y.
*Witherbee, W. C., ... Port Henry, Essex Co., N Y.
*Witherow, J. P., ... Market and Water Streets, Pittsburgh, Pa.
*Witherspoon, James, ... Laredo, Texas.
†Wittmack, Charles A., ... P. O. Box 1032, New York City.
*Wittman, N. B, ... Pittsburgh Steel Casting Co, Pittsburgh, Pa.
†Wolcott, Henry R., ... Denver, Colorado.
*Wolf, Theodore G., ... Scranton, Pa.
*Wolfe, Albert H., ... 696 W. Monroe Street, Chicago, Ill.
*Wolff, Dr. Fr. M., ... German Consulate General, New York City.
*Wood, A. B., ... Ann Arbor, Mich.
*Wood, Frederick W., ... Steelton, Dauphin Co., Pa.
*Wood, Thomas D., ... McKeesport, Pa.
†Wood, W. Dewees, ... 111 Water Street, Pittsburgh, Pa.
*Wood, W. J., ... Collinsville, Conn.
*Woodbury, L. S., ... Calumet, Mich.
*Woodward, E. H., ... 54 Cliff Street, New York City.
*Woodward, Richard W., ... 10 College Street, New Haven, Conn.
*Woodward, W. H., ... Wheeling, Ala.
*Wright, Charles E., ... Marquette, Mich.
†Wright, Harrison, ... Wilkes-Barre, Pa.

*Wright, James N., ... Calumet, Mich.
*Wright, Whitaker, ... 413 Walnut Street, Philadelphia.
*Wurts, Charles P., ... New Haven, Conn.

*Yardley, Thomas W., ... Troy, N. Y.
*Yeatman, Pope, ... Ste. Genevieve, Mo.
*Young, James B., ... Phœnix Roll Works, Pittsburgh, Pa.
*Young, W. D., . . . Corner Fifteenth and Etna Streets, Pittsburgh, Pa.

*Zacharias, H. C., ... Shamokin, Pa.
†Zukoski, Edmund L., ... 1829 Kennett Street, St. Louis, Mo.

Honorary Members, 5; Members, 1248; Associates, 165; Foreign Members, 49.

Deceased.

BLOSSOM, T. M.,	1876
BRIGGS, ROBERT,	1882
BRINSMADE, J. B.,	1884
BROWN, A. J.,	1875
CALDWELL, W. B., JR.,	1880
CAMERON, JAMES R.,	1881
CHISHOLM, HENRY,	1881
CLARK, HENRY G.,	1881
CLEMES, J. P.,	1876
CONVERSE, JAMES B.,	1883
DADDOW, S. H.,	1875
D'ALIGNY, H. F. Q.,	1875
DAVIDSON, D. R.,	1884
DE PEIGER, R. F. J.,	1883
DRESSER, CHARLES A.,	1878
DWIGHT, W. S.,	1883
FERNEKES, ANTON,	1884
FIRMSTONE, WILLIAM,	1877
FULLER, JOHN T.,	1880
GOULD, ROBERT A.,	1878
GRIFFEN, JOHN,	1884
GRUNER, L.,	1883
HALL, JAMES F.,	1884
HARRIS, STEPHEN,	1874
HEALY, MORRIS,	1881
HOLLEY, A. L.,	1882
HUNT, THOMAS,	1872
HUSSEY, C. C.,	1884
HYNDMAN, E. K.,	1884
JENNEY, F. B.,	1876
JERNEGAN, J. L.,	1881
LEE, WASHINGTON,	1872
LEISENRING, JOHN,	1884
LIEBENAU, CHARLES VON,	1875
LORD, JOHN C.,	1872
LORENZ, W., JR.,	1881
LOWE, FRANCIS A.,	1883
McINTIRE, HENRY M.,	1880
MACMARTIN, ARCHIBALD,	1881
MANTHEY, WILLIAM,	1883
MICKLEY, J. W.,	1880
MOORE, CHARLES W.,	1877
NEWTON, HENRY,	1877
NEWTON, ISAAC,	1884

TABLE

SHOWING THE OFFICERS OF THE INSTITUTE FROM ITS ORGANIZATION TO THE PRESENT TIME.

The offices of President, Vice-President, Manager, Secretary and Treasurer are indicated by their initials.

	1871	1872	1873	1874	1875	1876	1877	1878	1879	1880	1881	1882	1883	1884
Alexander, John S.,				M	M	M					M	M	M	
Asmus, George,								M	M	M				
Bayles, James C,										M	M	M		P
Birkinbine, John,													M	M
Blair, Thomas S,				M	M	M								
Blake, William P,	V	V	V	V		V	V							
Blandy, John F,	V	V	V					V	V					
Brooks, Thos B,		M												
Buck, Stuart M,													M	M
Burden, James A.,										V	V			
Burnham, William,												M	M	M
Church, John A,									M	M	M			
Cogswell, W B,				V	V									
Cook, Edgar S,														M
Coryell, Martin,	S	S	M	M	M									
Cox, E T,							M	M	M					
Coxe, Eckley B,	V	V	V	V		V	V	P	P					V
Coxe, Wm E C,									M	M	M			
Drinker, Henry S,							M	M	M					
Drown, Thomas M,		M	S	S	S	S	S	S	S	S	S	S	S	
Dudley, Charles B,										V	V			
Egleston, Thomas,	M	V	V	V			V	V						V
Eilers, Anton,					M	M	M					M	M	M
Ely, T N,												V	V	
Emmons, S F,													V	V
Firmstone Frank,			M		V	V								M
Frazer, Persifor,										V	V			
Frazier, B W,				M	M	M		M	M	M				
Fritz, John,					V									
Gaujot, E.,	M	M												
Heinrich, Oswald J,					M	M	M							
Hewitt, Abram S,		M	M	M	M	P								
Holley, A L,				V	P		M	M	M					
Howe, H M,									V	V				
Hunt, Robert W,						M	M	M					P	
Hunt, T Sterry,			M	M	M		P							
Kent, Joseph C,				V	V									
Kerr, W. C.,													V	V
Keyes, W S,										M	M	M		
Kimball, J P.,											V	V		
Lesley, J P,		M	M	M										
Lewis, James F,									M	M	M			
Macdonald, Charles,												V	V	
Maynard, George W.,	M	M	M	M										M
McCreath, Andrew S,												M	M	M
McNair, T S,	M													
Metcalf, William,								V	V		P			
Moffat, E S,													M	M
Munroe, H S.,											M	M	M	
Newberry, J S,						M	M	M						
Pearse, John B.,							V	V						
Pechin, E C.,		M	V		V	V								V
Petherick, Thomas,	M	M												
Pettee, Wm H,			M								V	V		
Potter, William B,								M	M	M				
Powell, J. W,												V	V	
Prime, Fred., Jr,	M	M	M											
Pumpelly, Raphael,	M													
Rand, Theodore D,			T	T	T	T	T	T	T	T	T	T	T	T
Randolph, J. C. F.,											M	M	M	
Raymond, R W.,	V	P	P	P		V	V							S
Richards, Robert H,									V	V				
Roberts, Percival, Jr,										M	M	M		
Rothwell, Richard P,	M	V	V		V	V						P		
Shinn, William P.,							V	V		P				
Smock, John C.,					M	M	M							
Swoyer, J H,	V													
Symons, W R.,	V	V	M	M										
Thurston, Robert H.,								V	V					
Thomas, David,	P													
Thomas, Samuel,									V	V				
Thompson, Charles O.,											V	V		
Wellman, S. T.,													V	V
Williams, T M.,	M													
Williamson, J. Pryor,	T	T												
Witherbee, Thos F.,						M	M	M						

LIST OF THE MEETINGS OF THE INSTITUTE AND THEIR LOCALITIES FROM ITS ORGANIZATION TO THE END OF 1884.

Number	Place.	Date.	Transactions.	
I.	Wilkesbarre, Pa.,*	May, 1871,	i.	3
II.	Bethlehem, Pa.,	August, 1871,	i.	10
III.	Troy, N. Y.,	November, 1871,	i.	13
IV.	Philadelphia, Pa.,	February, 1872,	i.	17
V.	New York, N. Y.,*	May, 1872,	i.	20
VI.	Pittsburgh, Pa.,	October, 1872,	i.	25
VII.	Boston, Mass.,	February, 1873,	i.	28
VIII.	Philadelphia, Pa.,*	May, 1873,	ii.	3
IX.	Easton, Pa.,	October, 1873,	ii.	7
X.	New York, N. Y.,	February, 1874,	ii.	11
XI.	St Louis, Mo.,*	May, 1874,	iii.	3
XII.	Hazleton, Pa.,	October, 1874,	iii.	8
XIII.	New Haven, Conn,	February, 1875,	iii.	15
XIV.	Dover, N. J.,*	May, 1875,	iv.	3
XV.	Cleveland, O.,	October, 1875,	iv.	9
XVI.	Washington, D. C.,	February, 1876,	iv.	18
XVII.	Philadelphia, Pa.,†	June, 1876,	v.	3
XVIII.	Philadelphia, Pa.,	October, 1876,	v.	19
XIX.	New York, N. Y.,	February, 1877,	v.	27
XX.	Wilkesbarre, Pa.,*	May, 1877,	vi.	3
XXI.	Amenia, N. Y.,	October, 1877,	vi.	10
XXII.	Philadelphia, Pa.,	February, 1878,	vi.	18
XXIII.	Chattanooga, Tenn.,*	May, 1878,	vii.	3
XXIV.	Lake George, N. Y.,	October, 1878,	vii.	103
XXV.	Baltimore, Md.,*	February, 1879,	vii.	217
XXVI.	Pittsburgh, Pa.,	May, 1879,	viii.	3
XXVII.	Montreal, Canada,	September, 1879,	viii.	121
XXVIII.	New York, N. Y.,*	February, 1880,	viii.	275
XXIX.	Lake Superior, Mich.,	August, 1880,	ix.	1
XXX.	Philadelphia, Pa.,*	February, 1881,	ix.	275
XXXI.	Staunton, Va.,	May, 1881,	x.	1
XXXII.	Harrisburg, Pa.,	October, 1881,	x.	119
XXXIII.	Washington, D. C.,*	February, 1882,	x.	225
XXXIV.	Denver, Col.,	August, 1882,	xi.	1
XXXV.	Boston, Mass.,*	February, 1883,	xi.	217
XXXVI.	Roanoke, Va.,	June, 1883,	xii.	3
XXXVII.	Troy, N. Y.,	October, 1883,	xii.	175
XXXVIII.	Cincinnati, O.,*	February, 1884,	xii.	447
XXXIX.	Chicago, Ill.,	May, 1884,	xiii.	
XL.	Philadelphia, Pa.,	September, 1884,	xiii.	

* Annual meeting for the election of officers. The rules were amended at the Chattanooga meeting, May, 1878, changing the annual election from May to February.

† Begun in May at Easton, Pa., for the election of officers, and adjourned to Philadelphia.

PUBLICATIONS.

The publications of the Institute comprise:

1. The minutes of the Proceedings of each Meeting, published in pamphlet form.

2. Such of the papers presented or read by title at each Meeting as are furnished by the authors and approved by the Council for full publication. (In nearly all cases in which papers, the titles of which appear in the Proceedings, are not subsequently published, they have been withdrawn by the authors.) These papers are published separately in pamphlet form, and are marked "Subject to Revision."

3. Annual volumes of *Transactions*, containing the list of officers and members, rules, etc.; the Proceedings and the papers, *revised for final publication.* (In this revision after the preliminary publication, authors are permitted to use the largest liberty; and the changes and additions made in papers are sometimes important. It should be borne in mind, by those who study or quote a paper in the preliminary edition, that they may not have in that form the ultimate and deliberate expression of the author's views. It should be added, however, that in the majority of cases there is no essential change, the correction of typographical errors and additions of later information being the usual alterations.)

4. Special editions of separate papers, for which there is demand. These are fully revised, and usually issued in pamphlet covers.

5. Books. (Under this head the only publications thus far have been an Index to Vols. I. to X. inclusive, a Glossary of Mining and Metallurgical Terms, and a Memorial of Alexander Lyman Holley.)

All the foregoing publications are sent free to members and associates *not in arrears at the time of publication.* They are also for sale at the office of the Secretary, or are sent to purchasers by mail or express, charges paid, on receipt of the price by the Secretary, as follows:

Classes 1 and 2, above mentioned,—price not uniform—a small sum, in no case exceeding 20 cents per copy, to cover cost of printing, storage, clerk-hire, postage, etc.

Class 3 (*Transactions*), at $5 per volume in paper covers, or $6 bound in half-morocco.

Class 4. This class now includes "Steel Rails" (Papers by Messrs. Sandberg, Dudley and Holley, and discussions at two meetings in 1881, from vol. ix. of the *Transactions*), price $1; "Technical Education"

(Papers and discussions at the XVIIth [Philadelphia] meeting, in 1876—mostly not in the *Transactions*), price 50 cents; "Russell's Improved Process for Lixiviating Silver-Ores," by C. A. Stetefeldt, price 25 cents; "The Law of the Apex" (including the Appendix), by R. W. Raymond, price 25 cents; "List of Members, Rules, etc.," price 25 cents.

Class 5. Index to Vols. I. to X., inclusive, of the *Transactions*, price, in paper covers, $1; in half-morocco, $2. "Memorial of Alexander Lyman Holley," in cloth, with frontispiece-portrait, price $2. "Glossary of Mining and Metallurgical Terms," by R. W. Raymond (from vol. ix. of the *Transactions*), in cloth, price 50 cents.

All communications and remittances should be addressed to R. W. Raymond, Secretary, P. O. Box 223, New York City.

RULES

ADOPTED MAY, 1873. AMENDED MAY, 1875, MAY, 1877, MAY, 1878, FEBRUARY, 1880, and FEBRUARY, 1881.

I.

OBJECTS.

THE objects of the AMERICAN INSTITUTE OF MINING ENGINEERS are to promote the Arts and Sciences connected with the economical production of the useful minerals and metals, and the welfare of those employed in these industries, by means of meetings for social intercourse, and the reading and discussion of professional papers, and to circulate, by means of publications among its members and associates, the information thus obtained.

II.

MEMBERSHIP.

The Institute shall consist of Members, Honorary Members, and Associates. Members and Honorary Members shall be professional mining engineers, geologists, metallurgists, or chemists, or persons practically engaged in mining, metallurgy, or metallurgical engineering. Associates shall include all suitable persons desirous of being connected with the Institute, and duly elected as hereinafter provided. Each person desirous of becoming a member or associate shall be proposed by at least three members or associates, approved by the Council, and elected by ballot at a regular meeting upon receiving three-fourths of the votes cast, and shall become a member or associate on the payment of his first dues. Each person proposed as an honorary member shall be recommended by at least ten members or associates, approved by the Council, and elected by ballot at a regular meeting on receiving nine-tenths of the votes cast; *Provided*, that the number of honorary members shall not exceed twenty. The Council may at any time change the classification of a person elected as associate, so as to make him a member, or *vice versa*, subject to the approval of the Institute. All members and associates shall be equally entitled to the privileges of membership; *Provided*, that honorary members shall not be entitled to vote or to be members of the Council.

Any member or associate may be stricken from the list on recommendation of the Council, by the vote of three-fourths of the members and associates present at any annual meeting, due notice having been mailed in writing by the Secretary to the said member or associate.

III.

DUES.

The dues of members and associates shall be ten dollars per annum, payable in advance at the annual meeting; *Provided*, that persons elected at the meeting following the annual meeting shall pay eight dollars, and persons elected at the meeting preceding the annual meeting shall pay four dollars as dues for the current year. Honorary members shall not be liable to dues. Any member or associate may become, by the payment of one hundred dollars at any one time, a life member or associate, and shall not be liable thereafter to annual dues. Any member or associate in arrears may, at the discretion of the Council, be deprived of the receipt of publications, or stricken from the list of members when in arrears for one year; *Provided*, that he may be restored to membership by the Council on payment of all arrears, or by re-election after an interval of three years.

IV.

OFFICERS.

The affairs of the Institute shall be managed by a Council, consisting of a President, six Vice-Presidents, nine Managers, a Secretary and a Treasurer, who shall be elected from among the members and associates of the Institute at the annual meetings, to hold office as follows:

The President, the Secretary, and the Treasurer for one year (and no person shall be eligible for immediate re-election as President who shall have held that office subsequent to the adoption of these rules, for two consecutive years), the Vice-Presidents for two years, and the Managers for three years; and no Vice-President or Manager shall be eligible for immediate re-election to the same office at the expiration of the term for which he was elected. At each annual meeting a President, three Vice-Presidents, three Managers, a Secretary and a Treasurer shall be elected, and the term of office shall continue until the adjournment of the meeting at which their successors are elected.

The duties of all officers shall be such as usually pertain to their offices, or may be delegated to them by the Council or the Institute; and the Council may in its discretion require bonds to be given by the Treasurer. At each annual meeting the Council shall make a report of proceedings to the Institute, together with a financial statement.

Vacancies in the Council may occur by death or resignation; or the Council may, by a vote of the majority of all its members, declare the place of any officer vacant, on his failure for one year, from inability or otherwise, to attend the Council meetings or perform the duties of his office. All vacancies shall be filled by the appoint-

ment of the Council, and any person so appointed shall hold office for the remainder of the term for which his predecessor was elected or appointed, *Provided*, that the said appointment shall not render him ineligible at the next annual meeting.

Five members of the Council shall constitute a quorum; but the Council may appoint an Executive Committee, or business may be transacted at a regularly called meeting of the Council, at which less than a quorum is present, subject to the approval of a majority of the Council, subsequently given in writing to the Secretary, and recorded by him with the minutes.

V.

ELECTIONS.

The annual election shall be conducted as follows: Nominations may be sent in writing to the Secretary, accompanied with the names of the proposers, at any time not less than thirty days before the annual meeting; and the Secretary shall, not less than two weeks before the said meeting, mail to every member or associate (except honorary members), a list of all the nominations for each office so received, stamped with the seal of the Institute, together with a copy of this rule, and the names of the persons ineligible for election to each office. And each member or associate, qualified to vote, may vote, either by striking from or adding to the names of the said list, leaving names not exceeding in number the officers to be elected, or by preparing a new list, signing said altered or prepared ballot with his name, and either mailing it to the Secretary or presenting it in person at the annual meeting: *Provided*, that no member or associate in arrears since the last annual meeting shall be allowed to vote until the said arrears shall have been paid. The ballots shall be received and examined by three Scrutineers, appointed at the annual meeting by the presiding officer; and the persons who shall have received the greatest number of votes for the several offices shall be declared elected, and the Scrutineers shall so report to the presiding officer. The ballots shall be destroyed, and a list of the elected officers, certified by the Scrutineers, shall be preserved by the Secretary.

VI.

MEETINGS.

The annual meeting of the Institute shall take place on the third Tuesday of February, at which a report of the proceedings of the Institute and an abstract of the accounts shall be furnished by the Council. Two other regular meetings of the Institute shall be held in each year, at such times and places as the Council shall select, and notice of all meetings shall be given by mail, or otherwise, to all members and associates, at least twenty days in advance. Special meetings may be called whenever the Council sees fit; and the Secretary shall call a special meeting on a requisition signed by fifteen or more members. The notices for special meetings shall state the business to be transacted, and no other shall be entertained.

Every question which shall come before any meeting of the Institute, shall be decided, unless otherwise provided by these Rules, by the votes of a majority of the members then present. Any member or associate may introduce a stranger to any meeting; but the latter shall not take part in the proceedings without the consent of the meeting.

VII.

PAPERS.

The Council shall have power to decide on the propriety of communicating to the Institute any papers which may be received, and they shall be at liberty, when they think it desirable, to direct that any paper read before the Institute, shall be printed in the Transactions. Intimation, when practicable, shall be given, at each general meeting, of the subject of the paper or papers to be read, and of the questions for discussion at the next meeting. The reading of papers shall not be delayed beyond such hour as the presiding officer shall think proper; and the election of members or other business may be adjourned by the presiding officer, to permit the reading and discussion of papers.

The copyright of all papers communicated to, and accepted by, the Institute, shall be vested in it, unless otherwise agreed between the Council and the author. The author of each paper read before the Institute shall be entitled to twelve copies, if printed, for his own use, and shall have the right to order any number of copies at the cost of paper and printing, provided said copies are not intended for sale. The Institute is not, as a body, responsible for the statements of fact or opinion advanced in papers or discussions at its meetings, and it is understood that papers and discussions should not include matters relating to politics or purely to trade.

VIII.

AMENDMENTS.

These Rules may be amended at any annual meeting by a two-thirds vote of the members present, provided that written notice of the proposed amendment shall have been given at a previous meeting.

PROCEEDINGS

OF THE

ROANOKE, VIRGINIA, MEETING.

JUNE, 1883.

ROANOKE MEETING.

COMMITTEES.

Citizens' Committee.

Roanoke.—J. B. Austin, Chairman; Frank Maddock, Secretary; P. L. Terry, F. Rorer, Henry S. Trout, Dr. F. Sorrell, David S. Read, Col. George P. Taylor, Charles M. Blackwell, Maj. Andrew Lewis, Capt. Marshal Waid, J. H. Dunstan, J. H. Sykes, H. Chipman, George T. Munford, Prof. William Taylor Thom, Col. D. F. Houston, J. Allen Watts, Capt. R. B. Moorman, Capt. M. M. Rogers, Dr. Joseph A. Gale, E. G. McClanahan, Capt. W. W. Berkely, F. J. Chapman, C. F. Conrad, Capt. W. W. Brand, S. S Brooke.

Lynchburg.—Gen. T. T. Munford, Mayor A. H. Pettigrew.

Botetourt County.—John C. Moomaw.

Liberty—Maj. S. Griffin.

Salem.—Col. Robert Logan, Prof. S. C. Wells, Col. C. W. Burwell, Dr. John S. Deyerle, John Chalmers, D. G. Armstrong, Judge Wingfield Griffin, Capt. George Horner, Col. Thomas Lewis, S F. Simmons, Col. E. W. Jack, Dr. J. W. Bruffey.

Wythe County.—Col. R. E. Withers, Gen. William Terry, Judge Robert C Kent, Maj. D. P. Graham, Maj. J. T. Hamlet, Maj. N. P. Oglesby, James H. McGavock, Judge John H. Fulton, Judge W. H. Bolling, David S. Peirce, Capt. John C. Raper, John W. Robinson, Gen. James A. Walker, C. S. Van Liew, Dr. Samuel C. Gleaves, Dr. R. E. Moore, John S. Crockett, Capt. Gibbony.

Abingdon.—W. K. Armistead, F. M. Imboden.

Montgomery County.—Maj. J. T. Cowan, Thomas W. Spindle.

Giles County.—John Graham, Jr., J. G. Osborne.

Local Committee in Lynchburg.

Capt. C. M. Blackford, Chairman ; John H. Flood, George M. Jones, P. J. Otey, W. B. Robinson, T. B. Deane, C. W. Button, T. D. Davis, H. Grey Latham, Alexander McDonald, L. S. Marye, John Stevenson, Jr.

Finance Committee.

P. L. Terry, Chairman; Henry S. Trout, Capt. M. M. Rogers, Col. D. F. Houston, F. Rorer.

Committee on Excursions.

W. W. Coe, Chief Engineer, Chairman; Col. Frank Huger, Supt. Norfolk & Western R. R.; Joseph H. Sands, Supt. Shenandoah Valley R. R.; Maj. Frank K. Huger, Supt. E. T. V. & Ga. R. R.; Thomas E. Matson, Supt. and Engineer E T. & W. N. C. R. R.; D. W. Flickwir, Asst. Engineer Shenandoah Valley R. R ; William Welch, Master Mechanic Shenandoah Valley R. R.

Committee of Members of the Institute.

J. H. Bramwell, Chairman ; W. A. Lathrop, C. R. Boyd, Dr. W. Lawrence Austin, James Witherspoon, J. Stevenson, Jr., N. Allen Stockton.

MUNICIPAL COMMITTEE.

Lucian H Cocke, Mayor; F. Rorer, S. W. Jamison, Henry S. Trout, J. B. Ferguson, D. W. Flickwir, Col. D. F. Houston; Committee of the Whole of City Council.

The opening session was held in the dining-room of the Hotel Roanoke on Monday evening, June 4th. Mr. J. B. Austin, chairman of the Local Committee of Arrangements at Roanoke, called the meeting to order, and, after a few words of cordial greeting, introduced Mayor Lucian H. Cocke, who in the name of the city welcomed the Institute to Roanoke. At the conclusion of his address the Mayor introduced Major S. Griffin of Liberty, who extended a welcome to the Institute on behalf of the State of Virginia. President R. W. Hunt replied for the Institute to the cordial addresses of welcome, and then read the following inaugural address:

ADDRESS OF PRESIDENT HUNT.

Upon assuming the duties of the high position to which you have elected me, I beg to thank you most sincerely for the honor conferred. To be the presiding officer of this society is a gratifying distinction; but entering upon that office as the successor of the able gentlemen who have preceded me renders me diffident as to the results of the ensuing term. But believing your hearts, rather than your cooler judgments, were consulted in making your selection, I, in self-defence, now rely upon them for forbearing criticism where weak, and warm support where strong and right.

Connected as most of us are with the active industries of the country, we are called upon to encounter not only engineering problems, but commercial ones as well. In fact, the two are so intimately associated, the success of one is the triumph of both. For while engineering difficulties may be overcome, if the result is not a commercial success, the world refuses to grant praise, and certainly withholds substantial rewards. I presume never since the organization of this Institute has the metallurgical engineer been called upon to meet a more embarrassing condition of affairs than at the present time. We have been through panics, through periods of depression and times of inflation; but just now, owing to the legislative status, an entirely new element enters into the problem.

After the warm words of graceful welcome to which we have just listened, with the certainty of having displayed to us, during the next few days of our visit to the storehouse of nature's treasures, such boundless mineral and agricultural wealth, made available by

intelligent enterprise and industry, it is next to impossible to realize the existence of aught but untrammelled prosperity.

Eight years ago, the President of this Institute, in his address at the Cleveland meeting, presented as he so well could the necessity for a general adoption of better methods, more economical machinery and saving appliances in all branches of manufacture. His warning words were uttered at a time when the business outlook was much the same as now. During the years which have elapsed since then, many steps have been taken in the right direction. But a period of great prosperity, at least of great activity, came upon us. Nature's refreshing rains and glowing sunshine made our fertile plains rich with golden harvests. Thousands from foreign shores came to us, seeking new homes in our God-blessed land. There has been work for all, plenty for all, demand for everything. The result was a feverish state of drive. Did the blast-furnace have a daily output of sixty tons, alter the lines—put up new stoves—another engine—force it—blow it—better still, build another and bigger one—produce two hundred tons per day! The Bessemer works were designed for and expected to make fifteen hundred tons of ingots per week. Put on three sets of hands, let the week of production begin on Sunday afternoon; the week of labor never end; and then, not be content with a weekly yield of three thousand tons. This has been the hot-blooded life of the past few years; but following it, have we not sometimes neglected true economy? If not, then well. But whether yes or no, the time is now here when we must have cheapness of production as well as quantity.

I take it, no matter what may be our views on the subject of protection, the supreme duty of every engineer is to aim at placing our industries entirely independent of the whole subject. An easy statement to make—not so easy of accomplishment. But our duty remains the same. How can it be done? Most emphatically not by placing American labor on the same basis as foreign; not by employing women and children to perform the work not of men alone, but that of beasts of burden; not by giving our workers hovels instead of homes; not by depriving them of wholesome diet; not by rendering education and advancement all but impossible; not by breaking down the barriers of morality; not by making the united efforts of a skilled man, his equally skilled wife and daughter, capable of yielding but $5.13 per week! I am proud to believe the reduction of labor to this point would require a plant for the construction of which the average engineering mind is incapable.

Unfortunately, when pinching times afflict us, when the necessities of curtailment of costs arise, we at once attack the wages problem as the certain and only way of salvation. That point of reduction of cost is so easily reached. Understand me; I do not mean that labor should not bear its share of depression, as it certainly always will of prosperity. But if we would give deeper thought, and not permit the human proclivity for hitting some other body satisfy us, we should make greater and more lasting savings. You may make a heavy reduction in wages, and save but a small amount per ton of product; and when times change, the reduction must be restored. But save a few per cent. of loss in the processes of manufacture, and your aggregate is the same, and that reduction in cost remains permanent. By the difference between an unintelligent, careless, and indifferent use of the non-producing supplies on one engine and its train of rolls and a conscientious effort at economy, an actual saving of one hundred dollars per month has been possible. This is not a fortune; but if you have say forty engines and thirteen trains of rolls, it merits respectful consideration. Better let that master mechanic's wages remain at a fair standard and have him save for you, than to take from him and let another lose for you. Hence, I argue that the first duty is seeking after better methods, then a rigid and economical administration, and *then* a revision of the whole labor question.

I think my statements as to not favoring a descent to the level of foreign labor have been sufficiently strong; but at the same time, I claim that the relative pay of our workers is not properly balanced. The machinists, the pattern-makers, the carpenters, the mechanics of America have to serve an apprenticeship of from three to four years, receiving during that time not more than enough to pay their board. After learning their trades, they can not hope for, in fact are satisfied with earning from two dollars and twenty-five cents to three dollars per day (the latter being for exceptionally skilful workmen), two dollars and fifty cents per day being about the average. Should these men develop sufficient talent, they may become foremen, at say $100 per month. Their employment demands physical skill, patient toil, frequently fearless exposure to physical danger, and a certain amount of intellectual education. The greater the latter, the more certain is the possessor of constant employment and success. From the daily wages stated, it of course follows that the yearly earnings are moderate. Nevertheless, in all manufacturing communities of this country, you will find that the

mechanics are, as a rule, the men who have acquired homesteads, who live with the most comfort, and whose children are prepared for a higher plane than that occupied by their parents. It certainly seems unjust that, as opposed to such a class of workers, other men without intellectual education, with trades that, with scarcely an exception, if sufficient physical strength is possessed, can be acquired in less than a year, should control a rate of pay from one and a half to three times as great. The young man in the machine-shop cheerfully devotes his time, while learning his trade, for a compensation of some three dollars per week. His fellow in the rolling-mill, if over eighteen years of age, must receive from a dollar and a half to two dollars per day, or he will remain in idleness. To my mind, true justice demands that the wages of the skilled mechanic should be the basis in comparison with which the rate of all other labor should be determined.

But to reach the sought-for plane, to place the manufacturers of this country in a position to compete in the open markets of the world, to render the question of tariff entirely one of revenue, one more thing is absolutely necessary: We must have cheap raw materials. No matter how much engineering skill is exercised, no matter how economical the administration, no matter how low the rewards of labor, unless the coal, the ore, the pig metal, are obtained at a far lower price than we now know, our market must be limited to our own domain, and the foreign importer must be handicapped by an impost; or else our furnaces must remain cold, our mills idle, and the mines of either my own New York or those of hospitable Virginia lie undeveloped.

To give us this cheap material, other than labor must be content with smaller returns. If the ore property is acquired for say fifty thousand dollars, the company formed to develop it must not have a capital of a million, and each stockholder expect at least ten per cent. on his watered investment. I fully appreciate that this is not likely to be received with favor; but if the demand is for steel rails at about twenty-five dollars per ton, to meet it the manufacturers must have pig-iron at the English price of say from twelve to thirteen dollars. Then, with the American converter, averaging 42,705 tons, against 20,920 for the English, and 15,001 tons for the French per year, there need be no fear but the American product can compete in any market, and at the same time pay labor as American labor should be rewarded. It has been demonstrated that freight can be carried over our railroads, and profits made, at a rate per mile that a few

years ago seemed impossible. Our country is one of long distances. The various raw materials are generally far apart, or else the market is distant. Hence railroad engineers and managers have already contributed their share toward solving a problem which, view it as you may, is one of at least not easy solution.

The advisability of such a policy has been recognized by at least one association of capitalists. The furnaces and mills located on the Hudson River, while possessing many advantages of location, have been handicapped by high-priced fuel. This must ever remain—and in the struggle of the survival of the fittest, there could be but one other element to offset this disadvantage. If cheap and good ore could be obtained, the distance from the coal-fields would be more than neutralized. To Mr. James A. Burden, of Troy, belongs the credit of a methodical investigation, rewarded by complete success, which promises to make the Hudson Valley one of the most favorable points for the production of cheap and good iron in the United States. The gentlemen associated with Mr. Burden in possession of the Hudson River ore property, and also the Chateaugay property, believe that their true interests point toward a large output at a small profit. Fortunately, the mixture of the Chateaugay and Hudson River ores in about equal proportions furnishes an easy working burden, and yields good foundry, mill, and Bessemer irons.

Taking Troy as a point at which these ores may be brought together and smelted in properly constructed furnaces, costs can be figured about as follows:

1 ton of Chateaugay, ...	\$6.50
1 ton of Hudson River, ...	
$1\frac{1}{4}$ tons of coal, ...	5.00
Limestone, ...	.50
Oil, tools, etc., ...	.50
Labor, ...	1.50
Repairs, etc, ...	1.00
	\$15.00

If Mr. Burden's policy is adhered to, it would seem as though hope still exists for some of us.

The bounden Christian duty of every one, in whatever sphere he may be placed, is to properly administer the talents given unto him. The seeking after the best methods in all things is imperative on all. But have we not cause to be proud of the development of our country, and reasonably well satisfied with the results? Coming, as we distant members of this Institute do, to partake of the hospitality and witness the Aladdin-like achievements of our hosts of this

section of Virginia, are we not inclined to conclude that the system which has rendered such things possible is fit to live?

Papers were then read by Mr. A. S. McCreath of Harrisburg, Pa., on The Iron Ores of the Valley of Virginia, and by Mr. C. R. Boyd of Wytheville, Va., on The Ores of Cripple Creek. The Secretary read a letter from the President of Roanoke College, Salem, Va., inviting the members to visit the college and to attend the annual commencement.

On Tuesday the members and ladies left on a special train, on the Norfolk and Western Railroad, for Lynchburg, where they were received by the local committee of arrangements, and other citizens and ladies, and transferred to a special train on the Richmond and Allegheny Railroad. The Lynchburg blast furnace of Messrs. Carter & Stevenson was first inspected, and the trip then resumed to Riverville, where transportation was provided by Mr. Thomas Dunlap to the mines of specular iron ore, about two miles from the station. A collation kindly provided by the citizens of Lynchburg was served at Riverville, after which short informal speeches were made.

Owing to unavoidable delays in returning to Lynchburg, the session appointed for the afternoon was abandoned, and the members spent the time, until the departure of the train to Roanoke, in inspecting a very extensive and interesting collection of ores and minerals, from the vicinity of Lynchburg, which were displayed in the rooms of the Chamber of Commerce. The citizens of Lynchburg had made all the arrangements for a banquet to be given to the members of the Institute on this evening, but the recent disastrous fire in the city, accompanied by loss of life, rendered an entertainment of this character inappropriate.

The second session of the Institute was held on Wednesday morning, in Rorer Hall, when the following papers were read and discussed:

The Coals of the Lower Measures or Conglomerate Group in the Virginias, and The Iron Ores of the Virginias, west of the Archæan or Eastern Blue Ridge. By Major Jed. Hotchkiss, of Staunton, Va.

Cast Iron of Unusual Strength. By Edward Gridley, of Wassaic, N. Y.

An Hypothesis of the Structure of the Copper Belt of the South Mountain. By Dr. Persifor Frazer, of Philadelphia.

The Porosity and Specific Gravity of Coke. By F. P. Dewey, of Washington, D. C.

Gold Mining in South Carolina. By E. Gybbon Spilsbury, of the Haile Mine, South Carolina.

Dr. Frazer exhibited a large aneroid barometer of aluminium made by Hicks, of London, provided with a case of cork. This barometer combines the well-known accuracy of Hicks's work with great lightness, being only one-third the weight of an ordinary barometer of the same size.

During the morning and afternoon many of the members visited the Rorer Iron Company's mines, a few miles from Roanoke, the Crozer Steel and Iron Company's new furnace, and the Roanoke Machine Works.

In the afternoon an excursion was made to the Upland mines of the Crozer Steel and Iron Company, after which the members and ladies were charmingly entertained by the citizens of Roanoke in the beautiful grounds and large hotel at Blue Ridge Springs.

The concluding session of the Institute was held in the hall of Blue Ridge Springs Hotel on Wednesday evening.

Mr. J. P. Witherow, of Pittsburgh, read a paper on The New Furnace of the Crozer Steel and Iron Company, followed by Professor C. H. Hitchcock, of Hanover, N. H., on The Geological Position of the Philadelphia Gneisses.

Dr. Egleston announced the death of Professor Gruner, of Paris, one of the honorary members of the Institute, and gave a sketch of his professional career. Mr. Charles A. Ashburner spoke of the great loss the Institute had sustained in the death of Mr. James Park, Jr., of Pittsburgh. President Hunt also spoke feelingly of Mr. Park's noble and useful life.

The following papers were then read by title:

Leaching of Gold and Silver Ores. By Dr. T. Egleston, of New York.

Treatment of Slimes. By F. G. Coggin, of Lake Linden, Michigan.

The Langdon Gas Producer. By N. M. Langdon, of Chester, N. J.

Determination of Manganese in Ferro-manganese, Spiegeleisen, etc. By Magnus Troilius, of Philadelphia.

The Copper Deposits of South Mountain. By C. Hanford Henderson, of Philadelphia.

The Shelf Dry-kiln. By C. A. Stetefeldt, of New York.

The Schwartzkoppf Control and Safety Apparatus for Steam Boilers. By C. A. Stetefeldt.

Repairs and Improvements at Cedar Point Furnace. By T. F. Witherbee, of Port Henry, N. Y.

Notes on the Geology of Alabama. Communicated by Dr. R. W. Raymond, of New York.

The Geologico-Geographical Distribution of the Iron Ores of the Eastern United States. By Professor J. C. Smock, of New Brunswick, N. J.

The Volumetric Determination of Manganese. By Mr. J. B. Mackintosh, of Hoboken, N. J.

Notes on the Construction of Large Chimneys. By P. Barnes, of Elgin, Illinois.

The following persons, proposed as members and associates of the Institute, and approved by the Council, were then unanimously elected:

MEMBERS.

Charles M. Atkins, Jr.,	Pottsville, Pa.
J. B. Austin,	Roanoke, Va.
P. H. Broun,	Pottsville, Pa.
D. W. Brunton,	New York City.
S. B. Christy,	Berkeley, Cal.
W. S. Clayton,	Baltimore, Md.
W. W. Coe,	Roanoke, Va.
Albert L. Colby,	New York City.
H. E. Colton,	Nashville, Tenn.
C. F. Conrad,	Roanoke, Va.
J. H. Converse,	Philadelphia.
Robert A. Cook,	Bethlehem, Pa.
Samuel A. Crozer, Jr.,	Roanoke, Va.
E. C. Darley,	St. Louis, Mo.
Isaac Fegely,	Pottstown, Pa.
P. L. Fox,	Philadelphia.
R. C. Fulton,	Conshohocken, Pa.
C. B. Going,	Cincinnati, Ohio.
John Graham, Jr.,	Pearisburg, Va.
F. A. Hemmer,	New York City.
G. C. Hewitt,	Winifrede, W. Va.
C. B. Houston,	Thurlow, Pa.
Henry G. Howe,	Tombstone, Ariz.
Edward S. Hutter,	Houston Mines, Va.
Thomas James,	Braddock, Pa.
E. Landsberg,	Aix-la-Chapelle, Prussia.
Walter L. Lawrence,	Linlithgow, N. Y.
R. H. Lee, Jr.,	Lewistown, Pa.
A. E. Lehman,	Philadelphia.
G. A. Longnecker,	Dillsburg, Pa.
James Meily,	Wilmington, Del.
Edward Orton,	Columbus, Ohio.

John C. Patterson,	Lebanon, Pa.
Leonard Peckitt,	Reading, Pa.
Enoch Phillips,	Catasauqua, Pa.
Frank M. Pierce,	New York City.
H. O. Reinhardt,	Chihuahua, Mex.
William E. Rider,	New York City.
William L Saunders,	New York City.
Erich Schaufuss,	Wilkes-Barre, Pa.
Otto Stalman,	Lake Linden, Mich.
William F. Staunton,	New York City.
John H. Strauch,	Pottsville, Pa.
George F. Swain,	Boston, Mass.
John J. Tierny,	Tremont, Pa.
C. S. Westbrook,	Keeneville, N. Y.
John Wilkes,	Charlotte, N. C.
Lewis Williams,	Bisbee, Ariz.
Eugene B. Wilson,	Drifton, Pa.
J. Marshall Young,	Easton, Pa.

ASSOCIATES.

Charles D. Bell,	Philadelphia.
J. Lawrence Campbell,	Liberty, Va.
J. C. Ferris,	Carthage, Ill.
F. L. Garrison,	Philadelphia.
E. B. Gosling,	New York City.
Dunbar F. Haasis,	Brooklyn, N. Y.
William S. Humbert,	New York City.
William B. Lamberton,	Harrisburg, Pa.
William Newbough,	New York City.
George S. Prindle,	Washington, D. C.
T. W. Ridsdale,	Brooklyn, N. Y.
T. W. Simpson,	Roanoke, Va.
Webster D. Smith,	Paint Creek, W. Va.
James B. White,	Pittsburgh, Pa.

The status of the following associates was changed to member:—W. P. Butler, N. W. Perry, E. G. Stoiber and H. A. Van Tassel.

On motion, it was unanimously voted that the secretary be directed to give suitable expression of the hearty appreciation of the members of the Institute of the courtesies which had been extended to them by the Shenandoah Valley, the Norfolk and Western, the Richmond and Allegheny, the East Tennessee, Virginia and Georgia, and the East Tennessee and Western North Carolina Railroad companies, by the citizens of Roanoke and Lynchburg, and by the many corporations and individuals who had exerted themselves to make the meeting successful and profitable.

The meeting was then declared adjourned, and the members and ladies returned to Roanoke for the night.

On Thursday an early start was made by special train on the Norfolk and Western Railroad for the Flat Top coal fields on the New River Division. At Pocahontas, the mines and coke ovens of the Southwest Virginia Improvement Company were inspected, and the members were kindly provided with lunch by the Company. Returning from Pocahontas, the party proceeded to Wytheville, where they were entertained for the night by its hospitable citizens.

On Friday the trip was resumed westward on the Norfolk and Western Railroad and over the East Tennessee, Virginia and Georgia Railroad, to Johnson City, Tennessee, where the narrow-gauge cars of the East Tennessee and Western North Carolina Railroad were in waiting and conveyed the party through wild, mountainous scenery to the Cranberry Mine (in North Carolina), of the Cranberry Iron and Coal Company. On arrival, General A. Pardee, Jr., President of the Company, received the members, who were given opportunity to inspect the underground workings. The party then returned to Roanoke, arriving about midnight.

During the two days of the excursion meals were served in the cars by the thoughtful generosity of the citizens of Roanoke and others of the local committees.

The following members and associates were present at the meeting:

William H. Adams,
E. C. Appleton,
Charles A. Ashburner,
J. B. Austin,
W. Lawrence Austin,
Edward Bailey, Jr.,
Richard D. Baker,
C. R. Boyd,
Alfred F. Brainerd,
George W. Bramwell,
J. H. Bramwell,
Stuart M. Buck,
L. Duncan Bulkley,
J. Lawrence Campbell,
R. C. Canby,
H. M. Chance,
James E. Clayton,
W. S. Clayton,
W. W. Coe,
H. B. Colburn,
C. F. Conrad,
Edgar S. Cook,
Samuel A. Crozer, Jr.,
Asbury Derland,
Fred P. Dewey,
E. V. d'Invilliers,
Henry S. Drinker,
Thomas M. Drown,
Thomas Dunlap,
T. Egleston,
Michael Fackenthall,
J. W. Farquhar,
Isaac Fegely,
Persifor Frazer,
John Graham, Jr,
Edward Gridley,
Edward Hart,
C. Hanford Henderson,
G. C. Hewett,
C. H. Hitchcock,
Jed. Hotchkiss,
C. B. Houston,
R. W. Hunt,
William Jolliffe,
Frank King,
C. O. Lagerfelt,

J. S. Lane,
Edward K. Landis,
N. M. Langdon,
W. A. Lathrop,
A. E. Lehman,
James F. Lewis,
John C Long,
J. A. Longnecker,
A. S McCreath,
Charles Macdonald,
William G. Neilson,
J. M. Ordway,
Edmund C Pechin,
Enoch Phillips,
John B. Porter,
T. D. Rand,
Ellen H. Richards,
R. H. Richards,
Percival Roberts,
Pedro G. Salom,
Richard H. Sanders,
P. W. Shimer,
Albert Spies,
E. Gybbon Spilsbury,
John Stevenson, Jr.,
John M. Stinson,
N. Allen Stockton,
H. A. Strode,
William Thaw, Jr.,
Willard P. Ward,
J. P. Witherow,
James Witherspoon.

PAPERS

OF THE

ROANOKE MEETING.

JUNE, 1883.

THE IRON ORES OF THE VALLEY OF VIRGINIA.

BY ANDREW S. McCREATH, HARRISBURG, PA.

I HAVE recently been called upon by the Shenandoah Valley and the Norfolk and Western Railroad companies to make an examination of the iron ores in the Valley of Virginia tributary to their lines of railway, and it has been suggested to me that a brief statement in regard to some of the more important points might prove interesting to my fellow-members of the Institute at this meeting.

The Valley of Virginia, so called, extends from the Potomac to the Tennessee line, a distance of about 330 miles. It forms part of the Great Limestone Valley which traverses in an unbroken line the States of New York, New Jersey, Pennsylvania, Maryland, Virginia, and Tennessee. In New York State it is called the Walkill Valley; in Eastern Pennsylvania, the Kittatinny Valley; in Middle Pennsylvania, the Lebanon or Cumberland Valley; in Virginia, the Shenandoah or Winchester Valley, the Roanoke Valley, the James River Valley, and the New River Valley; and further south, the Valley of East Tennessee.

Two ranges of mountains hem the valley in. The range on the southeast is called the South Mountain in Pennsylvania; the Blue Ridge, with its southwest prolongations Poplar Camp and Iron Mountain, in Virginia; and the Smoky Mountains in Tennessee. The range on the northwest is usually called the North Mountain; but it has such local names as Shawangunk, Kittatinny, Blue, and Brushy Mountain.

The primary rocks consisting of granitic strata (gneiss) and crystalline slates (mica slate, chlorite slate, etc.) form the Eastern Blue Ridge, while the Primal or Potsdam sandstone formation lies upon its western slope along the southeast edge of the valley.

The valley itself varies in width from ten to twenty miles, and its floor is composed of two different kinds of rock, limestone and slate, separated from each other by an irregular line running along the middle of the valley, its whole length; the limestone land stretching to the foot of the South Mountain, and the slate land stretching to the foot and up the slope of the North Mountain.

The North Mountain consists of Upper Silurian rocks,—Oneida conglomerate and Medina sandstone, Formation No. IV.; except in Southern Virginia, where by reason of the great upthrow faults, the Vespertine or Pocono sandstone, Formation No. X., makes the North or Brushy Mountain.

It will be sufficient, however, for my present purpose to consider only the two great geological formations: No. I., the Primal or Potsdam sandstone formation; and No. II., the lower Silurian limestone formation; for it is in these that nearly all of the ores which I have examined occur.

Formation No. I.

The Primal or Potsdam sandstone formation consists of conglomerates, sandstones, and slates, and it may be conveniently divided into (1) lower slates, (2) sandstones, and (3) upper slates.

First. In the *lower slates*, or those geologically underneath the Potsdam sandstone, occurs a red hematite ore, sometimes in beds of considerable thickness and of good quality. This is the so-called "specular ore" of the Blue Ridge, and it has been quite extensively developed at numerous points, notably in Botetourt and Bedford counties. In Northern Virginia the ore is generally very lean, being little better than a ferruginous sandstone. But over large areas it is a fairly rich ore carrying from 40 to 45 per cent. metallic iron, with the phosphorus varying from 0.25 to 0.60 per cent. The siliceous matter varies from 25 to 35 per cent., and consists for the most part of small grains of quartz. The ore occurs in beds varying from 18 to 48 inches in thickness, although beds of much greater thickness have been reported. The following is a complete analysis of a sample of this ore from the "Pollard cut" on the Arcadia furnace property in Botetourt county:

Protoxide of iron,	1.221
Sesquioxide of iron,	55.928
Sesquioxide of manganese,	.043
Alumina,	1.808
Lime,	.730
Magnesia,	.706
Sulphuric acid,	.007
Phosphoric acid,	.607
Water,	3.144
Siliceous matter,	35.690
	99.884

Metallic iron,	40.100
Metallic manganese,	.030
Sulphur,	.003
Phosphorus,	.265
Phosphorus in 100 parts iron,	.660

Second. In the *Potsdam sandstone* itself, important beds of iron ore have been observed. The ore is generally a close-grained, brittle, dark brown hematite, invariably cold-short. In Rockbridge County a bed of it fully ten feet thick is exposed for a considerable distance on the Vesuvius property.

The ores from this horizon will probably average 50 per cent. metallic iron, with about one and a quarter per cent. phosphorus. Their composition is such that they are peculiarly adapted to the manufacture of pig-iron for conversion into steel by the *basic* process; as it has been found that a pig-iron with about two and one-half per cent. phosphorus gives the most satisfactory results. The following complete analysis of a sample from the "cold-short" bank on the Vesuvius property, Rockbridge County, will show the ultimate composition of the ores of this horizon:

Sesquioxide of iron,	74.893
Sesquioxide of manganese,	.433
Sesquioxide of cobalt,	.030
Oxide of zinc,	none.
Alumina,	1.005
Lime,	.740
Magnesia,	.360
Sulphuric acid,	.012
Phosphoric acid,	3 357
Water,	11.318
Siliceous matter,	8.050
	100.198

Metallic iron,	52.425
Metallic manganese,	.302
Sulphur,	.005
Phosphorus,	1.466
Phosphorus in 100 parts iron,	2.796

Third. The *upper slates*, however, are by far the most important from an economical standpoint, forming, as they do, one of the richest repositories of brown hematite iron-ore in Virginia. They intervene between the Potsdam sandstone and the base of the calciferous limestone, and they are found all along the western slope

of the Blue Ridge—being geologically coextensive with it. They are generally more or less disintegrated, or decomposed into variegated clays; and while they may not always carry a continuous ore-bed, yet, wherever the formation exists, deposits of iron-ore of greater or less extent may be confidently looked for.

It is this horizon which has supplied a large amount of iron-ore to the blast-furnaces of Pennsylvania, and it has been the source of practically the whole of the stock of the old charcoal furnaces of the Shenandoah Valley; to the Shenandoah Iron Company's furnaces, from the noted Smith and Fox Mountain ore-banks, in Page and Rockingham counties; the old Mount Torry furnaces in Augusta; Cotopaxi, Buena Vista, Vesuvius, and Glenwood furnaces in Rockbridge, and the Arcadia and Cloverdale furnaces in Botetourt County. The new modern coke furnace recently established at Roanoke by the Crozer Steel and Iron Company will also be largely supplied with ores found in this formation at the company's mines in the so-called Cloverdale ore-belt.

It would be tedious to mention all the localities where large deposits have been developed, and are now being successfully worked; and the increased railroad facilities afforded by the completion of the Shenandoah Valley Railroad, will doubtless be the means of greatly stimulating their further development by more thorough and systematic methods of mining.

The average character of the ore is good, and in some localities it is exceptionally fine. The average of thirty-one carefully-selected samples shows the following: Metallic iron, 49.956; phosphorus, 0.399; siliceous matter, 12.459. The iron varies from 38.95 to 56.55 per cent., and the phosphorus from .061 to 1.266 per cent. Eighteen of the samples show considerably over 50 per cent. metallic iron, and only one sample shows less than 40 per cent.

The following complete analyses will represent the character of some of the more important deposits. The samples represent the *lump ore* alone; and the ores were dried at 212° F. previous to analysis:

	No. 1.	No. 2.	No 3.	No. 4.
Sesquioxide of iron,	74.678	75.321	77.643	74 571
Sesquioxide of manganese,	4.619	1.831	.568	2.038
Sesquioxide of cobalt,	.080	.130	.020	none.
Oxide of zinc,	.040	.050	trace.	none.
Alumina,	1.415	2.100	.747	.951
Baryta,	none.	none.	none.	.040
Lime,	.670	.550	.430	.550
Magnesia,	.320	.331	.324	.356
Sulphuric acid,	052	.025	.040	.040
Phosphoric acid,	.233	.609	.446	.444
Water,	11.810	12 398	10 310	10.822
Siliceous matter,	6 310	6.910	9.390	10 450
	100 227	100.255	99 918	100 262
Metallic iron,	52 275	52.725	54 350	52 200
Metallic manganese,	3 216	1.275	.396	1 419
Sulphur,	.021	.010	.016	.016
Phosphorus,	.102	.266	.195	.194
Phosphorus in 100 parts iron,	.195	.504	.358	.371

No. 1. Donovan property, Beverly Ore Company, Page County.
No. 2. Fox Mountain bank, Shenandoah Iron Company, Rockingham County.
No. 3. Buena Vista Furnace property, Rockbridge County.
No. 4. Houston mines, Nos. 5 and 6 openings, Botetourt County.

It has been part of my duties, as chemist for the Second Geological Survey of Pennsylvania, to sample and analyze every important deposit of brown hematite ore that has been opened up along the flank of the South Mountain in Pennsylvania—which is simply a continuation northwards of this same ore-belt. The average of forty-six samples from the Cumberland Valley shows: Metallic iron, 42.95; phosphorus, .464 per cent.; and it is believed that the brown hematite ores at present being mined in the Lehigh Valley will not average over 40 per cent. metallic iron in the furnace. It will thus be seen that the ores from this horizon in the Valley of Virginia rank considerably above the average.

In these upper slates are also found important deposits of manganiferous iron ores, some of which might be used in the manufacture of spiegel. The average of six samples analyzed shows: Metallic iron 31.64, metallic manganese 19.12 = 50.76, total metallic contents, with the phosphorus averaging .130 per cent. The variations are as follows: Iron, from 12.325 to 47.15; manganese, from 7.277 to 44.312; and phosphorus, from .061 to .265 per cent., with the average as stated above.

In addition to these, rich deposits of a very pure manganese ore

have been successfully worked for a number of years. Thus far the most important is that at the Crimora mines in Augusta County; and the deposit seems so large, and the ore is of such fine quality, that I give in detail the analysis of an average sample of the *lump ore*, now quite extensively shipped to England:

Binoxide of manganese,	81.703
Protoxide of manganese,	7.281
Sesquioxide of iron,	.533
Oxide of cobalt,	.354
Oxide of nickel,	.096
Oxide of zinc,	.623
Oxide of copper,	none.
Alumina,	.896
Baryta,	.829
Lime,	.880
Magnesia,	.630
Sulphuric acid,	none.
Phosphoric acid,	.171
Alkalies,	.467
Water,	3 405
Silica,	2.132
	100.000

Metallic manganese,	57 291
Metallic iron,	.373
Phosphorus,	.075

Formation No. II.

In the body of the Great Limestone Formation, No. II., are found innumerable caverns and pot-holes, now filled with brown hematite iron-ore. Although such deposits may prove somewhat irregular, yet their extent is often very great, and they have yielded large quantities of the finest quality of ore.

In the northern part of the Valley of Virginia these limestone ores have not been developed to any great extent, but in Southwest Virginia they have furnished practically the whole of the stock to the charcoal furnaces of the district. Commencing at Mack's Creek, near New River, and pursuing a course parallel to Poplar Camp and Iron Mountains for a distance of thirty or forty miles, they have been developed in large quantity and of remarkable purity. This is generally known as the New River-Cripple Creek ore-belt; and the cold-blast charcoal furnaces of Wythe County, whose iron is in such good repute for car-wheel purposes, draw their supply of ore exclusively from this belt.

The ore occurs generally mixed with clay in clefts and cavities in the limestones, and some of the deposits have been proven to a depth of over a hundred feet. The bulk of the ore is wash-ore, and the wash material will average fully one-half clean ore. At some points, however, the workings show quite a good deal of lump ore; and this not infrequently carries an appreciable amount of iron pyrites, which occurrence may be suggestive of the origin of the ore. The superior quality of the ore is shown by the analyses of seventeen samples from different localities, yielding an average of: Metallic iron, 54.514; phosphorus, 0.106; siliceous matter, 7.094 per cent. The iron varies from 49.35 to 57.20; the phosphorus from .048 to .197; and the siliceous matter from 3.60 to 13.93. Nine of the samples show over 55 per cent. metallic iron, and only one contains less than 50 per cent.; and in no case is the phosphorus over .200. The general character of these limestone ores may be represented by the following complete analyses:

	No. 1.	No. 2.	No. 3.
Bisulphide of iron,	none.	.064	none.
Protoxide of iron,	none.	.047	none.
Sesquioxide of iron,	76 214	80.618	73.107
Sesquioxide of manganese,	.051	.103	1.334
Oxides of nickel and cobalt,	.040	.060	.110
Oxide of zinc,	none.	.150	.220
Oxide of lead,	none.	.184	none.
Oxide of copper,	none.	trace.	none.
Alumina,	2.365	1.476	1.410
Lime,	.820	.750	.710
Magnesia,	.486	.515	.677
Sulphuric acid,	.157	.092	.012
Phosphoric acid,	.171	.110	.451
Water,	12.072	11.174	10 576
Siliceous matter,	7.480	4.500	11.510
	99.856	99.843	100.117
Metallic iron,	53.350	56.500	51.175
Metallic manganese,	.036	.072	.929
Sulphur,	.063	.071	.005
Phosphorus,	.075	.048	.197
Phosphorus in 100 parts iron,	.140	.085	.384

No. 1. Rich hill or Forney property, near New River.
No. 2. New River Mineral Company's property (Van Liew's).
No. 3. Speedwell Furnace property.

In addition to the ores already mentioned, I desire to call attention to another remarkable group of ores occurring in the Great

Limestone Formation, and found at several points in Southwest Virginia and Eastern Tennessee, viz.: red hematite and magnetic iron ores. These may be said to be as yet practically undeveloped, for the ores were found to be too refractory for the small cold-blast charcoal furnaces of the district, and the lack of railroad facilities prevented their finding an outside market.

Sometimes the ore is a dense, fine-grained, red hematite, with a steel-blue color on fresh fracture, as at the Sharp, Thomas, and Crockett banks in Sullivan County, Tennessee; again, it is a fine rich magnetic ore, as shown at the Ripplemead mine on New River near Pearisburg, Giles County, Virginia, from which about 5000 tons have recently been mined and shipped to Harrisburg, Pittsburgh, and other points. Sometimes the ore changes into brown hematite; and indeed all three varieties may occasionally be found in the same opening. But whether the ore be red or brown hematite, or magnetite, it seems to possess the uniform feature of being very free from phosphorus. An exception might perhaps be sometimes made as to the magnetite. At some points this has been found to be more or less impregnated with slaty material, and when this is the case, the phosphorus may run somewhat higher; for I have observed that quite an appreciable amount of phosphorus is sometimes carried in the slate. But when the ore is free from this slaty gangue, the percentage of phosphorus is invariably low; and even where the ore carries considerable slate, the phosphorus has never been found over one-tenth of one per cent. It may prove interesting to note here that the magnetite is generally strongly impregnated with carbonaceous matter, sometimes to the extent of two or three per cent.

At the Sharp and Thomas banks in Sullivan County, Tennessee, the ore (red hematite) is reported from 5 to 10 feet thick, between walls of limestone; but owing to the difficulty of reducing these hard, dense ores in the small local furnaces, the openings have long been abandoned. Increased railroad facilities and the present demand for high-grade ores will doubtless be the means of having these deposits receive the attention which the fine quality of their ore seems to justify. The analyses of 9 samples of the red hematite and magnetic ores yield the following average: Metallic iron, 62.094; phosphorus, .032; siliceous matter, 5.290. The iron varies from 56.05 to 66.47; the phosphorus from .020 to .051; and the siliceous matter from 2.39 to 7.90. Separate analyses of 4 samples of the accompanying brown hematite show an average of: Metallic iron, 54.532; and phosphorus, .031.

The following complete analyses will show the general character of these ores:

	No. 1.	No. 2.
Protoxide of iron,	12.117	1 928
Sesquioxide of iron,	66 607	90.214
Sesquioxide of manganese,	none.	none.
Alumina,	2.197	1 863
Lime,	1.890	.500
Magnesia,	1.982	.317
Sulphuric acid,	.150	.020
Phosphoric acid,	.082	.050
Carbonic acid,	1.806	none.
Water and carbonaceous matter,	5.458	1.834
Siliceous matter,	7.760	2.975
	100.049	99.701
Metallic iron,	56 050	64 650
Sulphur,	.060	.008
Phosphorus,	.036	.022
Phosphorus in 100 parts iron,	.064	.034

No. 1. Gollcher bank, Washington County, Virginia. Magnetic iron ore.
No. 2. Crockett bank, Sullivan County, Tennessee. Red hematite.

In view of the fact that the iron ores of the Valley of Virginia are of such superior quality,—and there is sufficient evidence that they exist in large quantity,—it may well be asked, why have they not been more largely developed? Two reasons may be given, and these are: 1. Previous lack of railroad facilities, and 2. An insufficient supply of fuel for reducing the ores in the blast furnace. Although ever since early Colonial times, numerous small charcoal furnaces have been operated from time to time, producing a fine quality of pig metal, yet the lack of facilities for getting their product to market, and the gradual diminution of their fuel supply, together with the ravages caused by the late war, have not only greatly retarded their extension but have prevented the establishment of other enterprises. These obstacles, however, have now been overcome by the completion of the Shenandoah Valley Railroad from Hagerstown to Roanoke, thus affording ample railroad facilities; and by the building of the New River division of the Norfolk and Western Railroad to open up the great Flat Top coal region, with its superior coking coals. The New River-Cripple Creek ore-belt will soon be supplied with convenient railway communication, for a branch road has already been located, and there are good prospects that the line will be built in the near future.

During the present year the two pioneer *coke* furnaces of the Valley have been started, and are now in successful operation. The Shenandoah Iron Company's furnace at Milnes Station on the Shenandoah Valley Railroad was blown in during the month of February, and it has been producing from 60 to 70 tons of coke-iron per day ever since. The Crozer Steel and Iron Company's furnace at Roanoke has just been started, and it promises a successful future, for it has all the modern and improved appliances combined with an intelligent management. Both of these furnaces will draw their supply of coke (made from Flat Top coal) from the ovens of the Southwest Virginia Improvement Company at Pocahontas. This company commenced operations in February, 1882, by opening up the Nelson or Big bed of Coal. They are now building 200 beehive coke-ovens, and they expect to have a daily production of at least 250 tons of 48-hour coke, which output can readily be increased to meet future demands. In addition to this, they will ship a thousand tons of coal daily. Already in their preparations for regular mining, they have taken out from the various drifts some 40,000 tons of coal. The main drifts are 9 feet wide and $8\frac{1}{2}$ feet high, and the mine will be worked by the double-entry system of mining. The quality of the coal is very fine, as shown by the following analysis of samples selected from five different points in the drifts—the samples representing a complete section of the coal bed from roof to floor:

Water,	.932
Volatile matter,	20.738
Fixed carbon,	73.728
Sulphur,	.618
Ash,	3.984
	100.000
Phosphorus,	.0013

This brief statement will suffice to show in a general way the mineral resources of the Valley. With a convenient supply of the finest quality of coke, which the Flat Top coal promises to furnish; with a great variety and abundance of excellent iron ore, which can be cheaply mined; and with good railroad facilities to markets in every direction, the iron interests of the Valley of Virginia seem assured of a prosperous future.

THE ORES OF CRIPPLE CREEK, VIRGINIA.

BY C. R. BOYD, WYTHEVILLE, VA.

It would be a quite congenial task to attempt to describe all that extraordinary mineral wealth which is now giving such prominence to the region from the James River to the Tennessee line, adjacent to the great lines of the Shenandoah Valley and the Norfolk and Western railways; but such a task would be impossible within the limits of any ordinary paper. Hence, in advance of the fifth edition of my book and map on the *Resources of Southwest Virginia,* I must restrict myself to a limited but most interesting subdivision of this remarkable mineral belt.

I ask you, first, to go with me sixty miles southwest over the firm roadbed of the Norfolk and Western Railway to a point near Martin's or Swansea; thence southwardly seven miles to the Culbertson-Clark ore-bank, on the northwest bank of New River, in Pulaski County, Va.—the best defined northeastern limit yet shown of the Cripple Creek-New River ore-basin. Though thrown out, apparently, just east of Clark's by the uprising of the floor, these extensive deposits continue southwesterly, in a general direction, along and on both sides of New River and Cripple Creek, through Wythe County into Smyth, a distance of more than forty miles, before the floor again rises, thus rendering the reading obscure. The geological position of this basin, in the lower part of No. II., is generally admitted. Its ores are brown and red ores of iron, with a large proportion of magnetic ore above water level; sulphuretted and red iron ores below; zinc carbonates and silicates, silico-carbonates, and blende; lead sulphurets and carbonates; small quantities of copper ores; barytes, in some places; manganese; manganiferous iron-ores; and limestones, which frequently graduate into dolomite.

Its average width is probably over a mile and a half, but the deep red from its ores stains the surface for a width of over four miles. The average thickness of these truly interesting measures from floor to roof exceeds, by my reading, nine hundred feet vertical in the lead and zinc or limestone band of ores alone; while the Potsdam and calciferous ores, outcropping on the rim of the basin, occupy strata of more than double this thickness.

Its cross-sections, of still greater interest, taken on lines N.W. and S.E. across the general strike, are at (1) Culbertson-Clark's; (2)

Rich Hill, Pulaski County; (3) McGavock, Squier, Graham, and Robinson, both sides of New River; (4) Bertha and Falling Cliff Zinc Mines, and Oglesby-Crawford's; (5) Peirce's Falls and Graham Old Banks, both sides of New River; (6) Wythe Lead Mines, and Walton, both sides of New River; (7) Van Liew, Brown Hill, both sides of Cripple Creek; (8) Peirce, Chadwell, Moore section, both sides; (9) Eagle, Ravencliff, Huddle section; (10) Francis, Mill Creek, Irondale section, of remarkable interest; (11) Dry Creek, Cave Hill, Speedwell section, both sides of Cripple Creek; and (12) the Cregger Bank sections of the White Rock Furnace, all in Wythe County.

This basin is separated by the Iron Mountain or Blue Ridge formation, prolonged from the equally interesting band of copper and iron pyrites and native copper of Carroll County, on the southeast, while on the north and northwest, within sixty miles, are two great lines of coal deposits (one of which includes Pocahontas), which inclose between them other series of valuable iron-ore deposits, such as those at Ripplemead, Chestnut Flat, Round Mountain, etc., which have an apparent southwesterly trend in the direction of the great deposits of salt and gypsum that lie in the Holston Valley at and above Saltville.

(1) *Culbertson—Clark Section.*

Ignoring for the present the massive beds of iron-ore of the underlying slates, the Cripple Creek-New River basin proper at Culbertson's Bank, Pulaski County, shows a face over seventy-five feet vertical of cellular brown iron ore, now being largely used by Wood's Radford Furnace. It yields, by analysis, 56 per cent. metallic iron, 4.00 silica, and 0 22 phosphorus in 100 parts of iron, if care is taken in the selection of limestone for use in the furnace. The opposite side of the river shows large masses of zinc and lead-bearing strata, as well as iron-ore of the same series.

(2) *Rich Hill Section.*

Next to Culbertson's Bank, two miles to the southwest, are the extensive deposits of Rich Hill, a tongue of land lying between New River and Little Reed Island Creek, an affluent on the south side. Over nearly the whole surface of this hill, from the water to an elevation of two hundred feet or more, the soil is stained a deep red by the weathering and disintegration of ore; and there is but a small portion of this whole area (a mile and a half N.E. and S.W. by half

a mile in width) that the magnet would not load itself when dragged over the surface. This might not have been regarded a phenomenal occurrence if the ore had not also given marked evidence of polarity fifteen feet below the surface.

Here are found the blue and white wavy limestones that characterize these lands, dipping 6° to 8° westward, with large outcrops of ore on the river-side of the hill-crest, as well as on the side next Little Reed Island Creek, half a mile south. There are about one hundred acres on Rich Hill holding two great bands or stratifications of iron ore, separated by thirty to thirty-five feet of limestone, which have a thickness, in places, exceeding twenty feet vertical, each, and no doubt average twelve feet each of clean ore for each band, making together an ore body twenty-four feet thick for the area mentioned. The Rich Hill ore contains, according to the analysis of Mr. A. S. McCreath:

Metallic iron,	53 350
Metallic manganese,	.036
Sulphur,	.063
Phosphorus,	.075
Phosphorus in 100 parts of iron,	.140

An average of seven analyses of the same ore, by Mr. F. P. Dewey, is as follows:

Metallic iron,	55.16
Phosphorus,	.0686
Phosphorus in 100 parts of iron,	.124

The bottom of this alternation of ore and limestone seems to rest on a quartzose band.

The ores now used at Reed Island furnace, close by, are obtained from the southwestern continuation of these bands of ores and rocks in lands adjacent to Rich Hill. They show exposures of ore exceeding eighteen feet vertical, with rocks dipping gently S.W.

The ore appears here, as in many other places in this great basin, as if pocketed at intervals in the limestone; but it is evident, from a long and close study of many pits and openings throughout the two great arms of the lead, that the several strata, which are distinctly iron-ore bands, were deposited in the same plane with a quantity of finely triturated limestone, probably in a proportion of two or three of the former to one of the latter. Now there is a bifurcation in the outcrop of this remarkable basin, one limb or arm pursuing a line

through the territory lying north of New River, beginning somewhere in the vicinity of Rich Hill; the other, pursuing a nearly parallel course along New River and Cripple Creek, mainly on the south side of both. Following one or the other of these two great limbs, we find the soil either deep red or highly impregnated with magnetic shot-ore, for the distance of forty miles. This condition, it may be conjectured, would hardly be maintained unless the ore itself were nearly continuous between the rocks.

At the Reed Island beds there is evident a remarkable continuity in the ore. The formation here, dipping 8° or 10°, with some variability, S.W., shows ore on the surface for more than a mile still further up Little Reed Island Creek, going under water (as to the greater masses of iron-ores) about Sayers's, where the pure sulphuret of iron shows below water surface, in the bed of the creek. Then the distinctly iron-bearing bands seem to be overlaid with those whiter limestones and dolomites that hold the ores of lead and zinc, which yield at Sayers's distinct masses of lead sulphuret,—as well, also, at Stephens's, close by. There is not less that 1000 acres of the Reed Island lands, outside of Rich Hill, which have the same or greater total vertical thickness of ore.

Mr. A. S. McCreath's analysis of ores taken from the furnace washer, gave the following:

Metallic iron,	55.300
Siliceous matter,	7.270
Phosphorus,	.085
Phosphorus in 100 parts of iron,	.153

It may well be accepted that much of the ore will yield results almost identical with those at Rich Hill; particularly if a careful selection is made of limestone for fluxing.

(3) *McGavock, Squiers, Graham, and Robinson Section.* (4) *Bertha and Falling Cliff Zinc Mines Section.*

The whole formation dips gently toward the west and southwest for some miles, and by the time we reach the cross section at McGavock, Squires, Graham, and Robinson, and the Bertha and Falling Cliff Zinc mines, three and one-half or four miles S.W. from Rich Hill and above Reed Island Creek, the main bodies of iron-ore bands are beneath, and the more distinctly lead and zinc subdivisions are on and below the surface for large areas. This is on the south side of the river, while the north side, in the direction of Graham's forge

and Cedar Run furnace, presents to view the outcrop of the northern limb of the same body of iron-ores, with, however, a small portion of the lead band showing at Cassell's on Reed Creek, near New River.

While there are flattering surface indications of iron-ore on these sections south of New River, the great masses of the ore seem to be chiefly silico-carbonates and oxides of zinc, remarkably free from lead. Squiers's Barren Springs property seems to have a valuable body of this ore; Bertha Zinc Company about 1350 × 2000 feet area; Falling Cliff, 1800 × 1700 feet area. The Bertha opening supplies a large tonnage annually, which is smelted in furnaces, now numbering 448 retorts, located at Martin's or Swansea, on the Norfolk and Western Railway, fifty-seven miles southwest of Roanoke. After three years' steady mining the Bertha mine presents an opening, E. and W. 425 feet, 60 feet average width, 28 feet average depth, with exploration 47 feet deeper still in ore. The whole area here, as well as that of Falling Cliff mine, has been very fairly explored by means of shafts, drifts, and many pits. The spelter made from it analyzed by P. DeP. Ricketts, Ph.D., gave the following:

Metallic zinc,	99.9629
Iron,	0.0371

Extensively used, as this spelter is, by our government mints, it is singular it does not assume a value equal to the highest known. It is now quoted next to Bergenport spelter.

The northern end of this cross-section, on the north side of New River, presents large areas of iron-ore ground, similar to that about Reed Island furnace, though probably not in such quantities. Deep mining in the hills, near deposits which have been supplying Cedar Run furnace, will no doubt reveal large masses of excellent iron pyrites, good for chemical purposes.

Reverting to the extreme south end of this section—about Oglesby's and Crawford's—its ores are cut off from those of Bertha and Falling Cliff Zinc mines, by the uprising of the floor, showing in a high ridge, known as Roaring Falls Mountain, the course of which is nearly E. and W. The Oglesby-Crawford ores are in the lower limestone bands, subjacent to the lead and zinc bands. There are here excellent iron ores, masses of manganese ore of great purity, and interesting developments of iron pyrites. These ore deposits, continuing westwardly, form the excellent beds from which Peirce's

Falls six-ton furnace, two and one-half miles west of Bertha mine, derives its ores.

(5) *Peirce's Falls Furnace and Graham Old Banks Section.*

Within one mile southeast of this furnace, at intervals of about one-fourth of a mile, large openings, 300 feet in length in two of them, and less in another, show a continuous deposit, exceeding fifteen feet in thickness, of cellular brown iron ore, and the surface shows the remarkable characteristics of Rich Hill over an area more than 400 acres in extent; there are, in truth, two bands of fine red and brown iron ores. This ore contains, by the analysis of Mr. McCreath:

Metallic iron,	57.200
Siliceous matter,	5.300
Phosphorus,	.074
Phosphorus in 100 parts of iron,	1.290

On the opposite, or north side of New River, north of the ridge which is the western prolongation of Roaring Falls Mountain, the same ores again show over areas equally large. Again and again, as you proceed southwestward towards the Wythe Lead Mine cross-section, the fields are deeply stained with the rich dye from the weathering ores, and nowhere does the magnet fail to come up heavily laden with the shot-ore when dragged through the surface dirt, and this, too, over a width of three miles, sometimes more, across the strike.

(6) *Wythe Lead Mines and Walton Section.*

The Lead Mines section is one of great value and scientific interest. Here, as at Bertha and Falling Cliff Mines, the main body of iron-ore is below, and the lead and zinc show conspicuously near the surface, with but little over-burden to be removed. For a distance on the strike of the outcrop (N.E. and S.W.) fully 2.9 miles, the general conditions have been fully proven by numerous deep shafts, tunnels, and test pits. The shafts and tunnels of the lead mines penetrate about 250 feet below the surface, but only a few feet below water, the mine hill being 250 feet high. The ores are silicate and carbonate of zinc, carbonate and sulphuret of lead, and zinc-blende in massive proportions, the latter varying with lead sulphuret all the way down, under the surface ores.

It may be observed by those curious enough to inspect this cross-section closely that the great body of lead and zinc ores and dolomite are in an apparently crushed anticlinal or arch, in what is familiarly termed Lead Mines Hill, distant about 3000 feet south of New River, at a point 500 feet below the lead-reducing works. The greater value of the ores in the convexity of this arch may be due to the fusion and possible concentration resulting from the heat of a great lateral pressure. For a short distance either side of the crest of the anticlinal, lines of stratification are apparently obliterated, and a homogeneous mass, more than 50 feet thick, horizontally, by a depth extending below water-level, seems to have participated in this action. This particular subdivision or band, here over 300 feet thick, appears to carry a very heavy percentage of zincblende with lead-sulphuret, the output often showing masses of pyrites, which are usually easily separated at the mouth of the shaft. In both directions from the line of the arch's crest, wherever it has been pierced, this is the case for about three miles along the strike. Though the lead-ores have been mined and made into pig-lead and shot for more than 100 years, the proportion of sulphuret ore mined is insignificant compared with what remains. The surface-ores, such as carbonates and silicates, now being mined at the rate of 1200 tons annually, are far from being exhausted, so great is the territory still untouched except by the test pits.

As to iron deposits, the greater masses are entirely beneath the lead and zinc band, and probably exist as 6 or 8 large bands of iron pyrites, 350 to 500 feet below the general surface of the locality, accompanied, I think, with three thin strata of a very pure red hematite, superposed, upon which are the lead and zinc bands; and dipping 15° to 20° southeast are alternations of limestone with red and gray shales, schists, and quartzose sandstones, 800 feet thick. These limestones hold, at intervals, an aggregate of about 20 feet of good iron-ore (cellular and shot-ore), as appears in the cross section toward its southeast end.

The northwest part of the section, north of New River, shows the lower subdivisions of alternating limestone and iron-ores, again outcropping at the surface in the ore bands, passing Walton's furnace.

From the Graham lands east of Walton, through by the Sanders and Walton ore banks, to this line of section, the quantity of high grade ore must be very great.

(7) *Van Liew—Brown Hill Section.*

Next, to the southwest, $2\frac{1}{2}$ miles, is the Van Liew and Brown Hill section, of more than usual value and interest. At this section we have left New River, as that stream comes in from the south just east of Van Liew, and receives Cripple Creek a little below or east-northeast. We are, therefore, in the Cripple Creek region proper.

This section differs somewhat in its arrangement from that at the lead mines. Its southern end brings to the surface the *lower* or *underlying bands* of limestone iron-ores, dipping gently northwards, while the last section's southern portion presented the *overlying* bands dipping southwards. I think the river coming from the south occupies a line of displacement. This is likewise a heavy lead and zinc-bearing section, and is one of the most important in the fine quality and apparent great quantity of its iron-ores. Its southern portion is generally mined in the interest of the Ivanhoe or Van Liew furnace of the Hendricks Bros., New York. Its northern portion, dividing also the lead and zinc interest, is chiefly owned by the Lobdell Car Wheel Co., of Wilmington, Delaware, and the ores of that portion are used at Brown Hill furnace.

The southern portion of the section, or about 3600 feet of it, south of the lead and zinc band, gently dipping north and northwest, shows six distinct bands of iron-ores, nearly the whole of which are either highly or lightly magnetic down to two or three feet below the surface.

The lead and zinc division is composed of clearly defined strata, below the decomposed ores, of bands of zincblende, lead sulphuret, iron pyrites and limestone, alternating near the upper side or roof strata, with barytes and iron sulphurets; the dip is 30° northwest. This dip going northwest over the northern portion of the section, continues one mile from Van Liew, reversing in the trough of the basin just south of Cripple Creek. Then, the dip rising going northwest, the whole ore-formation outcrops again about Porter's Cross-roads.

The pits and openings of the furnaces named show solid ore for more than 20 feet vertical in several of the separate bands. It is occasionally over 50 feet thick in one shaft. The whole measures here will, no doubt, aggregate a solid thickness of nearly 200 feet of iron-ore, separable into bands from 10 to 25 feet thick each. This locality shows over 1200 acres of accessible mining ground.

Analyses of the ores overlying the zinc band are as follows:

Analysis by J. M. Sherrerd.

Metallic iron,	55.702
Silica,	4.590
Phosphorus,	.0745
Phosphorus in 100 parts of iron,	.134

Analysis by A. S. McCreath.

Metallic iron,	49.350
Siliceous matter,	13.930
Phosphorus,	.109
Phosphorus in 100 parts of iron,	.220

Of those large bands underlying and within the lead and zinc band, Mr. McCreath's analysis is as follows:

Metallic iron,	56.500
Metallic manganese,	.072
Sulphur,	.071
Phosphorus,	.048
Phosphorus in 100 parts of iron,	.085

A sample of washed ore (mostly surface) gave phosphorus in 100 parts of iron, .131.

Two samples of pig-metal gave an average of

Silicon,	2.357
Phosphorus,	.145

An examination, with a not very strong magnet, of the ores in the pits showed them to be magnetic in some instances 20 feet below the surface. Those at the wash piles loaded the magnet at every trial. A test applied to the sediment at the washers showed it to contain more than 10 per cent. of magnetic ore in a finely divided condition. This would suggest that large quantities of very pure ore are lost that might be saved by some other process than washing. This fact is not only true of this locality, but of all others in this series. The sediment gathered from just below any of the washers, shows that there is a large proportion of the best ore lost.*

* This loss might be overcome by roasting all the output of the pits at the mine, screening and then driving the fine ore through a long horizontal flume (supplied with secure doors at intervals) by an air-fan. Nearly the whole of the ore would settle promptly by reason of its weight, and the mere dust would be driven farther. The doors could at any time be opened and the flume cleaned. This plan, if successful, would leave the once beautiful streams of this basin pure and limpid, making it possible for the fish to live in them, and the cattle, abounding in the fine grass fields, to drink of them, and would restore the landscape to its original beauty.

(8) *Peirce, Chadwell, Moore Section.*

This section, southwest two miles, is almost a duplicate of Van Liew, Brown Hill, and Porter's Cross-roads section, except that zinc and lead have not shown in any great quantity as yet. Between these two sections the surface is deeply dyed with the iron-ore stain, and nowhere does the magnet fail to pick up ore from the dust. The quantity of ore, similar to that at Brown Hill and Van Liew, is very large.

(9) *Eagle, Ravencliff, Huddle Section.*

This section, two and a half miles farther southwest, differs somewhat, as to its southern and middle portions, from the last two sections, the dip of rocks being somewhat changed. But there is very little difference in the quality of the ores, as they are in the same bands.

(10) *Francis Mill Creek, Irondale Section.*

This section is one the importance of which it will be difficult to overestimate, not only because of the large quantity of high-grade ores of the Cripple Creek series it holds, but of the vast reinforcement given to it by immediate contact with massive deposits of brown and specular ores of the underlying Potsdam series, all of which, owing to the nature of the exposures on high ground, can be cheaply mined. These several classes of ores, though in distinct beds, almost touching each other, have been brought close together by a great fault, or some change in the floor of the Cripple Creek basin not observed at other points; for the reading at many other accessible places makes them appear two thousand feet or more apart in the order of geological position. Be this as it may, in the cove above Hussy's Knob Gap, both on Francis Mill Creek and in the belt of red lands below this gap, the Irondale or Norma Mining Co. and Crockett & Co. own about fifteen hundred acres of strictly ore-lands, where the developments and the ore in sight would lead one to believe the quantity almost exceeds that at any other point. The Norma Company has openings, both large open pits and cross cuts, in all of the different bands of ores. Two bodies of the lowest or underlying series of ores, each about two-fifths of a mile in length, on both sides of the creek, show a thickness of from forty to one hundred and twenty-five feet of ore, with stripping-faces from eighty to six hundred and twenty-five feet above water-level. One of these veins of lower ores exceeds three hundred feet between its sides.

The upper horizon ores show well in the Porter Bank, north side

of Hussy's Knob, as well as in the area south of and above Hussy's Knob Gap, the former a mile and a half in length, the latter opened in many places over an area eight hundred yards one way by six hundred yards in another direction.

Analyses of ores from these banks are as follow:

No. 1 *Opening.*

	Analyzed by A. S. McCreath.	Analyzed by T M. Drown.
Metallic iron,	49.050	57.810
Metallic manganese,	3 155	not determined.
Sulphur,	0.041	"
Silica,	not determined.	4.170
Phosphorus,	0.179	0.104
Phosphorus in 100 parts of iron,	0.365	0.180

No. 2 *Opening (analyzed by A. S. McCreath).*

Metallic iron,	51.550
Siliceous matter,	7.760
Phosphorus,	0.126
Phosphorus in 100 parts of iron,	0.244

With some care in selection it is probable that large quantities of these ores will be available for Bessemer purposes.

The specular ore, by Dr. Drown's analysis, contains as follows:

Metallic iron,	65.26
Silica,	3.59
Phosphorus,	.138
Phosphorus in 100 parts of iron,	.211

The magnetic quality of the ores here is also quite a marked feature. The small six and ten-ton furnaces,—Wythe, Irondale, Beverly, and Ravencliff,—which have been using ores from these beds, from time to time, have thus far succeeded very well in proving the existence of large quantities without materially reducing the total amount. There is also another great body of ore that may well be named ferro-phosphoritic, containing by Dr. Drown's analysis 1.4 phosphorus, ready for the basic process.

(11) *Dry Creek, Cave Hill, Speedwell Section.*

This section is about two and a half miles southwest of the one last mentioned. It yields the excellent ores of the limestone horizon over a width measuring from a point three-quarters of a mile south of Cave Hill furnace to the north side of Cripple Creek and Speedwell furnace, a distance of two miles, air-line. The Gannaway

bank of these two furnaces yields ore—red, brown, and magnetic—in very large quantities, and of quite a superior character. The six to eight ore-bands in the usually gently dipping limestones of this section, the bottom of which has not been found at twenty feet in the first one, extend six hundred yards either way before they go under. Mr. McCreath found some of the ore-bodies sixty-five feet deep, of which the analysis was:

Metallic iron,	51.175
Sulphur,	.005
Phosphorus,	.197
Phosphorus in 100 parts of iron,	.384

Finally, we pass over the deeply-stained valley of Cripple Creek, four and a half miles southwest from Speedwell, to reach the last section taken.

(12) *The Cregger Bank of White Rock Furnace Sections.*

In the two sections taken here, through two large pits, an eighth of a mile apart, on the north side of Cripple Creek, the limestone and ore were found dipping 20° to 25° in a direction south and east. The line of section through the larger or lower bank, eight hundred and twenty-five yards in length, showed alternations of limestone and ore for two-thirds of the whole distance. The section through opening No. 2, four hundred and thirty yards in length, also presented the like alternations all the way.

The first pit is now 100 by 60 and 40 feet deep; the second is 60 by 30 and 15 feet deep. This ore contains, according to Mr. McCreath:

Metallic iron,	53.725
Siliceous matter,	7,770
Phosphorus,	.064
Phosphorus in 100 parts of iron,	.119

Some of these bands can be mined one hundred and seventy feet above water-level. They are those just underlying the lead and zinc band, and will prove to be not less than eight in number, varying in thickness from ten to fifty feet.

Cost of Making Iron.

Van Liew or Ivanhoe furnace is now making 25 tons of hot-blast charcoal iron per day from 45 tons of ore. The conditions at this furnace are exceptionally favorable. If we assume that it will take 2.13 tons of ore (run of the mine) to make a ton of iron on New

River and Cripple Creek, we may estimate the cost of making iron in this region as follows:

Charcoal.		Pocahontas Coke.	
2.13 tons of ore @ $1.35, . .	$2 87	2 13 tons of ore, . . .	$2 87
180 bushels of charcoal @ 6¼ cts,	11.25	1.23 tons of coke @ $3.10, .	3 82
Limestone, ...	43	Limestone, ...	43
Labor and incidentals, . .	3.10	Labor and incidentals, . .	3 10
Cost per ton of pig iron, .	$17.65	Cost per ton of pig iron,	$10 22

The Pocahontas coal is taken at 76 per cent. carbon. These estimates are for small 6 to 10-ton furnaces; the cost would be of course less with larger furnaces.

Carroll County Pyrites, etc.

The magnitude of the deposits of pyrites of iron and copper, with their valuable cap of hydrated peroxide of iron, only eight miles, air-line, south from the great deposits of New River, entitle them to be considered in this connection.

Measurements taken in more than thirty shafts, cross-cuts, and tunnels, in its fifteen miles of length, between some of its bolder outcrops, as between Betty Baker mines on the northeast end and the great outburst of surface ores west of Chestnut Creek, show the mineral body to be about thirty-three feet between walls, dipping about 40° to 45° south; and equally extensive explorations prove its continuity.

Above water level, in the creeks and branches, which cut across the strike of this great bedded vein every half-mile or so, there is stripping-ground fully two hundred and twenty-five feet on the inclined face of the ore-body. Measuring from the surface down, an average of thirty feet will be hydrated sesquioxide of iron, with crystals of copper carbonate in the lower portion. The next three feet will be oxide of copper and copper glance; the remainder, above water-level, or one hundred and ninety-two feet, will be mundic or iron pyrites, with a variable proportion of copper pyrites, containing, on an average, 2½ per cent. of copper and 45 per cent. of sulphur, the residue being mainly iron and gangue. A very considerable deduction has been made for intrusions of gangue, for the vein is sometimes seventy-five feet thick between its walls of talcose slates and schists.

The body of pyrites in this length of fifteen miles, which has been thoroughly explored, may be claimed by a not unreasonable

conjecture to be 10 miles in length (throwing out one-third for loss in ravines, etc.), by 192 × 33 feet.

Rio Tinto, in Spain, with its vast deposits of a similar nature, is not more extensive. It would be easy to mine it at a cost not exceeding forty cents per ton, and it is then down-grade to shipping points. One of its most accessible points is near Early's, or Cranberry Plains, Carroll County, Virginia.

LEACHING GOLD AND SILVER ORES IN THE WEST.

BY THOMAS EGLESTON, PH.D., NEW YORK CITY.

The process of lixiviating silver ores, which do or do not contain gold, by means of hyposulphite of soda is likely to assume a very great importance in the West, the conditions being such that while it is applicable to very rich ores which do not contain lead enough to smelt, it is also equally applicable to many ores that are either too poor or too impure to be treated by any other process. Western ores are generally divided into four classes: those which contain copper enough to be smelted for copper, from which the gold and silver is extracted in the wet way, as is the practice of the Boston and Colorado works; those in which there is a large quantity of lead, which can be smelted for lead, and the gold and silver extracted from it; ores in which there is neither copper nor lead enough to allow of a process of smelting, but which can be treated in pans, these ores being "free milling" if they require no metallurgical treatment, or "rebellious" if they have to be roasted with or without the addition of salt; and ores which do not contain enough either of lead or copper for smelting, which are poor both in silver and gold, contain large amounts of sulphur, arsenic, and antimony, and cannot be treated in many places in the West by any of these processes. Roasting with salt would convert the base metals as well as the silver into chlorides, and would give in the amalgamation a very base bullion, and the expense of the process would be so great that the margin of profit would be very small, the reason being that for the ordinary process of pan-amalgamation, which is the only one suitable for ores containing small amounts of the base metals, and poor in silver and gold, the cost of a plant for milling is so large as not to justify the expense of treating such ores. The electrolytic processes which have been partially successful in Europe have not been tried here. While in the near future they will undoubtedly be used, it is hardly possible to consider them now.

They can only be used near great centres of population, or where the amount of ore to be treated is so very large that it would justify a very expensive plant. When the trial period is passed this method will undoubtedly be applicable to many ores whose treatment is not now even discussed as possible. There are very large quantities of low-grade ores containing about thirty ounces of silver, with little or no gold, to the ton, which might be treated if a not very expensive plant could be used.

The process of leaching with the hyposulphites of soda or lime has not attracted much attention in the West as yet, partly because imperfect experiments made with it in a small way have not been successful. It has also been thought that, while the price of salt is very low in these regions, it would be impossible to use any amount of a reagent which was high-priced like hyposulphite of soda. As far as the chemicals are concerned, while the price of salt is very low, all the salt, in any process where it is used, is lost. This expense is, therefore, a considerable one when very large quantities of ore are treated; and though the price of hyposulphite of soda is high, the amount consumed is extremely small, since all but a very small portion of the liquid is saved, as most of it is regenerated and used over again. There are very few places in the West where lime cannot be had. The use of sulphide of calcium, which is so easily made as a precipitating reagent, makes it quite possible to use the leaching process, as this gradually transforms the hyposulphite of soda into hyposulphite of lime, the use of which has a great advantage in the treatment of ores containing even a very small quantity of gold, as the hyposulphite of lime dissolves nearly the whole of the gold, and allows of its being extracted while the hyposulphite of soda does not. The quantity of water used with pan amalgamation must always be at a maximum, even though it is used over again.* The quantity used with hyposulphite leaching is always a minimum, since all the water used in the process can be used over and over again, even the washing water being serviceable, so that the loss of water will be very small. In addition to this the plant which is to be used is a very cheap one, being composed of roasting furnaces, which need not be of a very expensive type, of wooden tubs, of not very costly materials, and requiring for the most part only low-priced labor. The process, however, requires careful watching by an expert, and continual assays, in order to see that there is no waste of silver or of the reagent.

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* Engineering, vol. xvii., p. 516.

Besides this, the California practice invariably associates with the pan the California stamp, which has always been considered one of the best machines for crushing. In the case of surface ores, however, especially such as contain silver, either in a native state or as chlorides or bromides, or where they contain sulphide of silver, the stamp is a very bad machine, because it tends to beat out the pieces so thin that they float, or in case of brittle ores to make flour, and in this way permits of their being carried off by the water. Later European practice shows that this has such an effect in enriching the tails that rolls are there gradually taking the place of stamps. The rolls simply crush or disintegrate the material, and are much less expensive than the stamps. But even supposing the stamps to be replaced by rolls, the rest of the amalgamation plant—the furnaces, pans, and settlers—is costly, requires constant repair, and must, in a period more or less short, wear out and be replaced. The mercury is, too, an expensive and troublesome reagent. The consequence is that the capital required for a leaching plant is very much less than it would be in a milling one. The leaching process is also applicable to ores containing both gold and silver, for when hyposulphite of soda is used after the ores have been leached for silver, the tails can be treated by Plattner's process, and the gold and the silver both recovered in a state of high bullion, so that a parting process would not be necessary, and when hyposulphite of lime is used they are recovered together. It is also applicable to ores very rich in silver as well as to very poor ores, whether they are or are not very impure or are contaminated with other metals, since, when it is worth while to do so, small amounts of copper, cobalt and nickel may be separated.* There is, however, a limit to the quantity of base metals, especially lead, which can be treated. This will depend in every case on the quantity of silver and on the cost of reagents. It is never applicable to ores which contain lead enough to smelt.

In some cases where the ores were very rich in pyrites but poor in gold and silver, a matte concentration has been made and the extraction done on the roasted matte. Such an application necessitates a cheap fuel, but the concentration can be carried on so as materially to reduce the amount to be treated. In Mexico† this process has been used on the amalgamation tails, containing large quantities of lead and 0.24 per cent. of silver.

It is not, however, to be supposed that the process has no disad-

* Annales des Mines, 5 series, vol. viii., p. 68.

† Zeitschrift fur das Berg-Hütten-und Salinen-Wesen, vol. xxi. (1873), p. 143.

vantages. While the plant is very inexpensive, it requires carefu attention on the part of those in control of it, for although the reactions are exceedingly delicate they can be learned by men of very ordinary capacity, provided they are properly superintended; but the least carelessness on their part, either in the roasting, leaching, or precipitation, or by adding too much or too little of the reagent, involves very serious losses.

The process has assumed some importance of late from its use at the Old Telegraph and Lexington mills, the works at Triumfo, in Lower California, and from the erection of a large plant recently at the Geddes and Bertrand mine in Secret Cañon near Eureka, Nevada, where a poor ore full of impurities is treated. I have thought that a description of the process as used in these localities would be of interest. I have therefore described no mill in particular, though most of the details refer to the Bertrand mill.

The analysis of the ore from the Bertrand mine is given below:

Silicic acid,	50.25
Iron,	8 06
Zinc,	7.62
Lead,	4.64
Arsenic,	0.73
Antimony,	1.35
Silver,*	0.17
Lime,	4.92
Magnesia,	2 40
Sulphur,	0.96
Carbonic acid,	8.30
Water,	3.30
Loss and Oxygen,	6 80
Alumina,	trace
Bismuth,	"
Copper,	"
Potassium,	"
Sodium,	"
	100.00

The process consists of seven different operations:

1. Crushing the ore.
2. Drying the ore.
3. Roasting it with salt.
4. Leaching out the base metals with water.
5. Leaching with hyposulphite of soda.
6. Precipitating the silver.
7. Roasting the sulphide of silver and melting for bullion.

* About $50 per ton. Most of the ore is, however, of a lower grade than this.

1. Crushing the Ore.

The ore of the Bertrand mine comes from a higher level than the mill. It is brought in wagons drawn by horses and is dumped into a tunnel leading to the mill, falling through a shoot into cars on a track running into the highest level of the mill. Eventually a tunnel will be run directly to the mine, which is about a fourth of a mile distant, and the ore will come to the mill without previously discharging.

From the cars the material is dumped upon a grizzly, which is an inclined iron grating allowing only the small pieces to pass, and sending the large ones directly into a crusher, which after breaking them up discharges them into the same bin into which the small pieces which passed through the grizzly have fallen. From this bin the ore falls through a shoot into cars which carry it to the driers. In some works the large pieces pass through two sets of crushers, and what passes through the grizzly goes into a second crusher set fine, into which all the ore which does not pass the screens also falls. The ore is crushed so as to pass a 15 to 20-mesh screen. 30-mesh screens were first used, but it was found that the material did not discharge from these as well as from a coarser mesh, and that there was no necessity of treating the ore finer, as the roasting and leaching were better done on the coarse ore. Experience has shown that with the coarse screens more ore can be treated in a given time, as it leaches faster and there is less fine material to clog the filter. With fine ore it sometimes takes six or seven days to leach, and even then it is imperfectly done. In making an examination of the effect of coarse and fine screens it was found that in using those with from 20 to 40 meshes, 31 per cent. of the ore passed through; from 40 to 60-mesh screens, 14 per cent.; from 60 to 80-mesh screens, 6 per cent.; and finer than this scarcely an appreciable quantity passed, without mechanical agitation such as comes from the blow of the stamp or the agitation of the screen. The size adapted to each ore can only be determined by experience, as ores which are apparently the same act differently in leaching. The only general rule that can be given is that the ore must be crushed just as coarse as is consistent with perfect chloruration* in the furnace, which can easily be determined by trial. This question has received but little attention. It has more importance

* The word chloruration is used to describe the formation of chlorides by means of salt, in contradistinction to chlorination, used to describe the formation of chlorides by means of chlorine gas.

than is generally attributed to it, and when improperly done easily translates itself into both a diminished output and a loss of money.

The ore, wet before passing through the driers, assayed September 28th, 1882, $26.71; on September 29th the assay was $29.85, and on the 30th, $23.85. These assays were taken from a large car into which a sample from every mine car is thrown. The mean of these three is $26.80, which is a little low, the net assays being about $30. They are given because the other assays are made on charges made the same day.

2. Drying the Ore.

The ore is damp when it comes from the mine and is taken from the crusher to the driers. These are revolving wrought-iron cylinders, 20 feet long by 4 feet in diameter at one end and 3 feet at the other, known under the name of Pacific driers. The iron work for the driers weighs about ten tons; they are not lined. The flame from the fireplace runs directly through them, the ore being fed at one end automatically by the Hendy's Challenge automatic feeder, and dumped out into cars at the other end of the drier, without manipulation. These driers are usually heated by a fireplace of their own, which, however, is not absolutely necessary, as the flames from the Brückner's cylinders might be made to pass through them and then be made to pass into the dust chambers, thus utilizing a large amount of waste heat. When only small samples of ore are to be treated they are carried to a special bin, and put through a Dodge crusher, which is used almost exclusively for sampling. Drying-floors, made by passing the waste heat through flues covered with cast iron plates, are used in some works. This saves the fuel used in the driers; but this economy is more than compensated for by the labor required, the driers being automatic in their action.

After the ore leaves the drier it is carried to a bin from which it passes over a 15-mesh screen, and falls through a shoot in which is arranged a system of magnets to catch any pieces of metal which may have accidentally got into the ore, either in the mine or in the mill, such as bits of broken picks or drills, as they would be likely to injure the rolls, if they were allowed to pass through them. The ore then passes through two sets of Krom rolls, 16 by 24 inches, from which all that passes through the screens is carried by a chain elevator to a storage bin in the upper part of the building. What fails to pass the screens is carried back and put through the

rolls again. The ore from the rolls assayed on September 28th, 1882, $27.75; on September 29th, $25.13, and on the 30th, $24.19.

3. Roasting the Ore with Salt.

From the storage bin the ore descends through a shoot into cars standing on a track scale, where it is weighed. The contents of the cars are dumped into a hopper above the Brückner's cylinders, the amount of each charge passing into the hopper being carefully weighed. The moment the hopper is discharged into the cylinder beneath another charge is put in. The salt is not weighed. It is measured in soap-boxes which contain about 80 pounds each, and is mixed with the ore either in the driers or in the hoppers; formerly five per cent. of the weight was mixed with the ore. This amount was gradually decreased until now only three per cent. is used.

A number of experiments have been made as to the best place to add the salt. Formerly it was always added in the hoppers, and became thoroughly mixed by the movement in the cylinders. Now it is added in the driers, and by incorporation resulting from the movement there and in the rolls it has been found that the quantity of salt may be considerably reduced, so that they now do not use more than a third of the salt they formerly did. Very extensive experiments have been made in Europe on the best place to add the salt in the various metallurgical works where salt is used for the extraction of the metal, which has resulted in the adoption of a very ingenious mixing machine, into which the ore and salt are charged, which has produced great economy in the use of salt and better subsequent working. Both methods are successful, but the introduction in the drier seems the best, as it takes the place of the mixer in the European methods. At first two per cent. of iron pyrites was mixed with the ore in order to insure a proper roasting. The quantity was diminished little by little until now none is used. In most cases, however, where there is a large amount of base metals this addition will be necessary.

All the conveying of the ore is done with chain-elevators having pockets 6 by 4 inches. These are used for the dry ore only; the chloridized ore is not elevated. Repairs to these chain-elevators are very easy, for when a link is broken it has only to be taken out and another one put in, or if for any reason it is desirable to make the chain shorter or longer the links can be readily removed or added.

The ore is now ready to be roasted. This may be done in any kind of a furnace. Where transportation is difficult a reverberatory

furnace, with a hearth arranged in three steps, so that the ore in passing from one to the other falls a distance of 4 to 5 feet, would be the best. A Stetefeldt furnace could also be used to advantage. The iron work, as it is in pieces of no very great weight, can be easily transported, but is more expensive to build than a reverberatory furnace, which can always be easily adapted to any kind of fuel. At the Bertrand mill, which is within easy reach of San Francisco by railroad, there are four Brückner's cylinders, which are 7 feet in diameter and 19 feet long, and hold a charge of about five tons. The fireplace is on a prolongation of the axis of the furnace, but was formerly put at right angles to it, greatly to the inconvenience of the workmen. The cylinder is driven by friction-rollers, of which there are three sets, and not by a gear-wheel round the body of the cylinder as in the older form. The work is continuous, the furnace never being allowed to become cool. As soon as a charge has been treated a fresh charge is immediately put in. To introduce the charge the man-hole is brought under the hopper and its valve drawn. It is then replaced and the cylinder set to revolving two to three turns per minute. The amount of sulphur contained in the Bertrand ores is exceedingly small, so that the salt in very small quantity, if it has not already been added in the driers, may be introduced at once. When ores containing a large amount of sulphur are used, a careful roasting at a low temperature must precede the chloruration, steam at a low pressure being introduced for the purpose not only of getting rid of the last trace of sulphur, arsenic, and antimony,* but also to decompose the chlorides of the volatile base metals, the nascent chlorine thus given off acting very energetically on the silver. When the ore contains base metals which it is desirable to save,† this roasting must be done with great care, and the value of the base metals separated must compensate for the extra expense in fuel owing to the use of steam in the roasting. If lead is present, the roasting must be done at a low temperature, for as the compounds of lead are easily fusible, there might be danger of agglomeration; or, if the temperature is high and silica is present also, a silicate of lead might be formed which would prevent the solution of the silver. Special care must be taken in such a case to transform all the lead into chloride, as this is soluble in hot water, while the sulphate is not.

The roasting lasts eight to eleven hours, depending on how the

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* Engineering, vol. xxii., p. 515.

† Annales des Mines, 5 series, vol. viii., p. 70.

charge works. When it is finished the man-hole is opened without stopping the cylinder, which in its rotation discharges the ore, which falls into pits cut out of the rock in the foundation, just underneath the cylinders, where it is allowed to remain about nine hours, until it is ready to go to the cooling floor. These pits have been found to be a very great advantage, for it has been ascertained that a considerable amount of chloruration takes place in the pit after the charge leaves the furnace, so that the time of waiting is not lost. It is red hot when it falls into the pits, but cools sufficiently to be drawn off into cars after that time. Occasionally the ore, when for any reason there is a stoppage, remains for two or three days in this bin and is still hot when drawn. Generally, however, it is drawn out on the cooling-floor as soon as possible, where it is at once moistened with water to keep down the dust. Sometimes the ore is put into the tub so hot that the water boils, but this is not usual. The ore is generally cold enough not to make any appreciable difference in the temperature of the water. When the ore is one which is not habitually treated, a sample is drawn through the fireplace in order to test the chloruration. When, however, the ore is that which they are constantly using, they recognize that it is finished by its rolling about in the furnace with a sluggish motion somewhat like that of damp sugar.

When the furnace is discharging two assay samples are taken from every charge. When about half the charge of the furnace has run out a long iron spoon is run underneath and filled and its contents assayed. One of these samples is used for a chloruration test, which is made at once for each charge, each assay sample being marked with the number of the charge and of the furnace or the cylinder; the other is thrown into a large iron car to be afterwards used in making the general assay to ascertain the amount of silver contained in the ore.

The following table gives eleven assays of the ores taken from each of the furnaces during different days:

ASSAYS.*

No. of charge.	No. of furnace.	Value.
74	1	$25.44
75	1	30.16
81	3	32.36
81†	3	31.42

* I am indebted for these and the following assays to my pupil, Mr. C. F. Pearis, who was for some months assayer at the Bertrand mill.

† After remaining two days in the bin.

No. of charge.	No. of furnace.	Value.
84	2	28.27
85	3	33.30
86	3	27.96
115	4	30.16
116	4	27.96
117	4	25.75
118	4	27.33

Occasionally the charge of ore from the furnace is more than the tub will hold. This residue is put into a heap, and when enough of it has accumulated to fill a tub it is leached and called a "mixed charge."

On September 28th, 1882, the ore from the cylinder assayed $32.99; on September 29th, $30.47; on September 30th, $27.96. These assays on the same charges and days are interesting, and are given below together.

	Sept 28.	Sept 29.	Sept. 30.
Damp mine sample, . . .	26.71	29.85	23.88
Sample from the rolls, . . .	27 65	25.13	24.19
" " Brückner's cylinder, .	32.99	30.47	27 96
" " " " .	32.36	. . .	30.32

The assay for chloruration is made on the sample taken from the charge. Fifteen ounces are weighed out and put into a funnel with a proper filter. Hyposulphite from a tank above is let on to it and allowed to run from fifteen to twenty minutes, the filtrate being collected and sent to the leaching tubs. When no silver is dissolved the assay is washed and dried, and a fusion assay made of the tails. Twenty-three such assays are given in the table below.

CHLORURATION ASSAYS.

No. of charge.	No. of furnace.	Value.	No of charge.	No. of furnace.	Value.
81	3	$5.49	111	2	$3.92
81*	3	5.20	112	2	3.61
101	1	5.18	113	2	3.77
102	1	4.40	114	2	4.24
103	1	2.98	184	4	3.29
104	1	4.40	185	4	4.08
105	1	3.77	186	4	3.14
106	1	4.71	187	4	3.45
107	1	3.14	188	4	3.45
108	2	3.77	190	4	4.55
109	2	3.45	198	4	3.29
110	2	3.61			

* After remaining two days in the bin.

The following tables give the details of 24 charges in the cylin ders during a period of six days. They give a complete record o the work of the furnace during that time. The corresponding table for the tubs, and also the chlorination and tub-tailing assays are given on pages 58 and 59. These tables comprise the details o the entire work of the mill for four days.

Number of furnace	Number of charge.	Ore. Tons.	Ore. Lbs.	Salt, lbs.	Pyrites, per cent	Cars of flue-dust.	Hours roasting.
	Mixed charge	5		450	2		
2	67	5	532	720	2	3	10
	Mixed charge.	5		450	2		
2	68	7		720	2		7¼
2	69	7	803	720	2		8
	Mixed charge.	5		450	2		
2	70	7	1041	720	2	4	11
2	71	5		720	2	3	9½
2	72	6	1758	480	2	5	9½
2	73	7	50	720	2		8¾
3	74	7	140	700	2		13
3	75	5	600	480	2		7¾
4	88	5	1612	640	2	2	7¼
4	94	7	440	720	2		10
4	95	6	1116	720	2	1	8¾
4	96	5	1835	720	2	2	8½
4	97	7	140	720	2		10
4	98	4	134	720	2	3	9½
4	99	7		720	2		10½
4	100	3	667	640	2		9¼
4	101	7	1800	720	2		9¾
4	102	7	220	720	2		8½
	Mixed charge.	5		450	2		
	Mixed charge.	5		450	2		

The Brückner's cylinders are run by an upright engine with a cylinder 10 by 12 inches.

When the ore in the collecting-bins is sufficiently cool, it is drawn into cars and taken to a brick cooling-floor, where it is dampened with water and spread out with hoes. The collecting-bins are 12 feet deep and extend from the bottom of the cylinders to the top of the car on the floor below. The works are built on the side of a hill, which is a very convenient arrangement. No attempt is made to keep ore ahead. It is the intention to have two charges on the cooling-floor and one charge in each of the furnaces and a charge in each of the hoppers. The roasting is done by two men on each shift, each man tending two cylinders, with two Chinamen bringing the wood which is used as fuel.

All the machinery other than the Brückner's cylinders is run by an engine with a 14-inch cylinder with a 48-inch stroke, which is much larger than is required for the work. 12 cords of wood are burned in the 4 Brückner's cylinders in 24 hours. The wood is cedar, nut-pine, and mountain-mahogany, which are all excellent

woods. They are equal to or even better than the lignites which are the usual fuels of the country, judging them by weight. The driers burn three cords of wood per day, the engine four, the stoves to heat the leaching-room one. 20 cords of wood are used for the 24 hours for the entire work of the mill.

One engineer on each shift runs the boilers and the engine. He is a Chinaman and has one helper, who is also a Chinaman.

A considerable amount of chloride of silver and of dust containing silver is volatilized or mechanically carried off from both the Brückner's cylinders and the driers. It is, therefore, necessary to have dust-chambers connecting with both of these. The flues have a down-take, which communicates with a large chamber by an arched opening, which is quite small. The dust accumulates in considerable quantities at the bottom of the down-take, so that they are obliged to clean it frequently. This material and that which comes from the dust-chambers is collected. It is then passed through the Brückner cylinders and mixed with the charges as shown in the table, p. 50. Fresh salt is added to it and it is put through the tubs. Sometimes, when large quantities are on hand, it is treated separately.

4. Leaching the Base Metals with Water.

The leaching-room contains 24 tubs, 12 on a side, each of which is six feet in diameter and three feet deep, the depth being regulated according to the facility with which the water will filter through the ore, and also to the ease with which a man can throw out the tails. It would be much better to increase the diameter of the tubs to twelve feet; it is done in many of the works in Lower California and Mexico, the depth being the same as here. Experience in these countries has shown that a better result is obtained with large than with small tubs. These tubs are set on the floor together in pairs, the two tubs almost touching each other, with a railway upon one side and an easy passage-way between each pair of tubs. The track runs close to the side of the tubs. That the discharging may be done with facility, the wagon which receives the tails comes just above the top of the tubs, so that a man standing in them can easily throw the tails out into the wagon.

Permanently fixed above the tubs are hoppers, which are long and narrow. They are divided into two compartments, and have at their bottom a slit-valve, so that the ore may be discharged from each compartment in little piles over all parts of the bottom of the tub. Each tub may have its own hopper, made of iron, as at the Bertrand

mill, or one hopper may answer for two or more tubs, the discharge being made by flexible pipes. Stop-cocks or plugs do not answer for the leaching tubs, as they are apt both to get out of order and to leak. A rubber pipe can always be securely fastened to the bottom or side of the tub, and when not in use can be hung up out of the way. The ore is passed from the cooling-floor to the vats as rapidly as it can be handled, each charge of ore being drawn from the furnace-bins to the cooling-floor as soon as the latter is empty. The cars from the cooling-floor run over the top of the hoppers and dump their contents into them, which from there fall into the tubs when the slit-valve is opened, and the ore is afterwards evenly distributed over the bottom of the tub with a hoe. The charge could as easily be put into the tubs from a car running on a railroad at a sufficient height above the tub not to inconvenience the workmen in discharging it, and arranged with a valve like the hopper, or it could be dumped into the vat from the side.

The bottom of the tubs is covered with four or five wooden slats, three inches by one, which do not touch the sides. Over these, at right angles, are arranged other slats from an inch to an inch and a half apart. Gunny-sacking, which is wet from the previous charge, or is wet purposely when a new filter is to be put in, is placed over these. It is brought close up against the sides of the vat, so that no ore will pass, by means of a hoop, which fastens it securely there. The ore falls from the hopper upon this canvas and rises to within two or three inches of the top of the tub. When the ore is once in the tub, special care is taken that it shall not be disturbed in any way. Once ready for the water it is allowed to remain without being disturbed until the tails are ready to be discharged. Any interference with the arrangement in the tub increases the difficulty of leaching. The simple pushing of a stick two or three times down through the ore may delay the leaching several hours.

In the bottom of the tub are two india-rubber pipes, about 1½ inches in diameter, one for introducing the water and the other for discharging it. When hot water is used for leaching out the base metals the ore is always wet from the bottom, the water being introduced through the pipe and coming up through the ore. It has been found that this method of moistening the charge causes the ore to cake less and the solutions to percolate through them much more easily than when the water was introduced from above. As soon as the water completely covers the ore the supply is cut off. After remaining there for a very short time, the discharge-pipe, which has

up to this time been hung up higher than the top of the tub, is lowered and the water allowed to run out; the leaching water is added at the same time. This water is permitted to flow away entirely or is collected, according to the quantity of water available. The water used for the base-metal leaching may be hot or cold. If the ore contains a large amount of lead which has been converted into chloride it will be best to leach with cold water until the larger part of the lead and the surplus salt has been dissolved out. It is then leached with hot water, cooling the ore, however, with cold water before the hyposulphite is added, in order to prevent too great an extraction of the base metals with the silver. When the ore filters slowly it will be found best to heat the water, which will not only make it filter more easily, but will dissolve the base metals more rapidly. When the charge comes warm from the cooling-floor, when introduced into the tub, the water grows warm from the heat. In such a case, unless the ores are very pure, or where very impure ores have been leached with hot water, the charge must be cooled with cold water before introducing the hyposulphite, or the bullion would be much more impure.

As the water introduced from the bottom subsides, a very thin crust is formed upon the top of the charge, which is carefully removed and put by itself until sufficient accumulates to be treated. This material is quite rich in silver. It contains all the silver which was dissolved by the excess of salt or other chlorides in the ore, and which would have been lost if the hot water had been introduced at the top. This amount is all the larger if the solutions are hot, or if the excess of salt is large, as a hot brine dissolves more silver according as it is hot and saturated, while a cold one dissolves hardly any. The dilution of the liquor with water precipitates part of the silver near the top and distributes the rest of it through the ore, so that but little is lost in bottom leaching. The top crust is collected in barrels; there is but a small quantity on each tub, but, as there are 24 tubs constantly in use, it amounts to considerable by the end of the month. After this has been removed clear cold water is allowed to run in at the top, the quantity being regulated so that the inflowing water will just be equal to the quantity discharged, in order to leach out the base chlorides which are soluble. Any salt in excess, or any which has not been decomposed in the roasting, will be dissolved at the same time. When the ore contains but little base metal there is no advantage in using hot water. This is the case at Triumfo, in Lower California, where the ore is always leached cold and the water introduced from the top.

When the ore, however, contains a great excess of lead or antimony, the method of introducing the water from below is not sufficient, as the chlorides of these metals also are precipitated from the solution by dilution with water. In such a case the water is introduced from the top and the liquid allowed to flow from several tanks into compartments filled with shavings, so as to get a large amount of surface. Clear water is allowed to flow into these compartments, so as to make the liquor very dilute. The moment the fresh water touches the stream containing the chlorides, which was formerly clear, it becomes cloudy, and then precipitates the chlorides. Flowing over so large a surface, and being obliged to pass under one compartment and over the other, the chlorides of silver, lead and antimony deposit on the shavings, and can be dissolved from them with hyposulphite and the solution put with the other silver solutions. The water running off contains the zinc, copper, and iron. At Triumfo the ore contains four per cent. antimony and but little lead. No attention is paid to the antimony, the ores being leached with cold water. In Mexico the washing is repeated, the ore being discharged from the first tub to be put into a second. The first washing lasts for four hours and the second a little less; the observation having been made that even when no metal salts are found in the wash-water of the first washing some are found in that of the second; and only when nothing is precipitated from the second washing is the leaching with hyposulphite begun. In the West but one washing is generally made.

When the water flowing from the tubs no longer gives a precipitate when tested with sulphide of calcium, the base-metal chlorides are removed. When there is plenty of water, as at certain seasons of the year, all of this water is allowed to run to waste, if the ore contains no nickel or cobalt or other metals which are worth collecting. When, however, the water is scarce, or the base metals are valuable, it is all collected in the vats. The base-metal chlorides are precipitated with sulphide of calcium and the water used over again. It takes a quantity of water equivalent to three tubfuls to leach the base-metal chlorides out.

5. Leaching with Hyposulphite of Soda.

The washed ore is now leached with a cold solution of hyposulphite of soda. The strength of the solution will depend on the richness of the ore and the quantity of base metals present. If the ore

is very rich and but little base metal is present it may be used very strong, and even warm; but when base metals are present too much of them would be extracted, so that the solution is usually made weak and used cold. At Triumfo the quantity used is generally one pound to eight gallons of water. At the Bertrand mill it contains from half to three-fourths of a pound to the gallon. The hyposulphite is usually purchased. It comes to the works in small kegs, containing from 50 to 60 pounds each, and does not usually cost more than five to six cents a pound. It is generally cheaper to purchase it than to make it. The liquors increase in quantity as the solutions are constantly being regenerated, so that but small additions have to be made, and this only to keep up the strength of the solution, as the liquors are constantly being diluted. The hyposulphite is likely to become impure when the ores are not properly leached with water to dissolve out the sulphate of soda and chloride of sodium; it is generally the practice then to regenerate it by spreading wood ashes over the ore and leaching through that, the alkalies in the ashes taking up the sulphates and the excess of chlorides. By the constant use of the polysulphide of calcium it gradually becomes converted into hyposulphite of lime. It is sometimes desirable, especially when the ore contains gold, to use hyposulphite of lime, especially as the polysulphide of calcium which is used for the precipitation of the silver is the first step in the process of manufacturing it. This is done by boiling 1.5 parts of the purest freshly slacked lime that can be had with one part of crushed brimstone. Flowers of sulphur sifted through a fine sieve is also used, but it does not answer so well as the brimstone, which can be more readily obtained and is more easily manipulated. If the lime is not very pure it may be desirable to use two parts of lime to one of sulphur. When sulphur is scarce and high-priced it is sometimes collected from roasting the sulphide of silver. The water is first boiled with steam, the lime is added and well stirred, and the sulphur is then introduced. Sufficient water must be added to keep the mass liquid, but not enough to allow of the solution of polysulphide becoming too much diluted. The boiling is kept up from three to four hours. During this time polysulphide of lime, mixed with hyposulphite of lime, is formed, as shown by the formula below:

$$3CaO + 12S = 2CaS_5 + CaS_2O_3.$$

This operation requires some care. If lime is added in excess insoluble compounds are apt to form. Sometimes bisulphide of lime

is formed, which crystallizes out as reddish-yellow crystals. An excess of sulphur, however, does no harm, and may be useful in the next operation. The liquid is allowed to settle and the clear liquid decanted. It is desirable that this solution should be from 8° to 10° Baumé, and only sufficient water is added to bring it up to that strength. The liquid is now treated with sulphurous acid, made by boiling charcoal broken to about the size of a grain of corn, with sulphuric acid of about 1.80° B., enough being used to make a pasty mass. This is done in an iron retort, adding the acid to the charcoal as it is necessary. There is no necessity of purifying the gas. When the yellow color of the liquid disappears the sulphide has been converted into hyposulphite. This is tested with a dilute solution of chloride of silver. So long as there is any precipitate or cloudiness the passage of the sulphurous acid must be continued; when there is none the solution is ready. The residue in the tub is now treated with the same amount of water as before, and the operation commenced over again. If the resulting liquor is not more than 3° to 4° B., it is too weak, and is kept to treat the next charge of lime. The process used at Triumfo is much simpler. The residues left in the tub after the clear sulphide liquid is decanted are simply shovelled out and left for three or four days exposed to the sun. They are then leached with water, which extracts the hyposulphite of lime, after which they are thrown away. This method is a very rough one, as the oxidation is necessarily very imperfect, but for that situation is a much more economical method than the use of sulphurous acid.

The sulphide of calcium made in the first stage of the process is the material used for precipitation. It should not be less than 6° B. if used for that purpose. In some works the polysulphide of sodium, made by boiling soda with sulphur and treating it with sulphurous acid to make hyposulphite of soda, is used. This reagent does not precipitate the silver so rapidly, nor so well, and is not so easily washed. For this reason the hyposulphite of lime is preferred. Sometimes sulphuretted hydrogen, made by melting paraffine and flowers of sulphur together, is used for the precipitation. This is much more disagreeable than the other method and is not so frequently used. Where hyposulphite of soda is used, the constant addition of lime transforms the solution gradually into hyposulphite of lime. The strength of this solution is constantly kept up with a hydrometer.

When the ore is very impure, it is generally best to keep the so-

lution at about $\frac{1}{2}°$ Baumé. Before turning the solution into the precipitating vats, care must be taken to see that the water used for leaching out the base metals has been displaced. This is easily done by tasting, as the hyposulphite of soda and silver has an intensely sweet taste, or better by testing the liquor flowing from the tanks with sulphide of calcium. As soon as the least turbidity is shown, it is time to catch the liquor, as the hyposulphite is acting. This hyposulphite liquor is allowed to run through as long as it has a sweetish taste. No special attention is paid to the time at the Bertrand mill, as the work is done by Chinamen whose records would not be very intelligible or trustworthy; tests only are relied on. The reaction which takes place is

$$2AgCl + 2Na_2S_2O_3 + 5H_2O = 2NaCl + 2NaAgS_2O_3 + 5H_2O.$$

This hyposulphite of soda and silver is exceedingly soluble. The quantity of hyposulphite, and also the time required for leaching, will depend on the richness of the ore, more time being required for a rich thân for a poor one. Ores are rarely treated that require a longer time than twenty to thirty hours. An ore containing from $300 to $400 a ton, will be perfectly leached in twelve to fifteen hours. The time required at the Bertrand mill is from six to twenty hours, depending on the ease with which the hyposulphite filters.

As soon as the hyposulphite ceases to taste sweet, the solution is tested with sulphide of calcium to ascertain whether the ore is exhausted of silver. The tester carries a small bottle of the sulphide solution in which he has a stick. He takes a tumblerful of the liquid running out and lets a drop or two of the sulphide fall into the liquor in the glass. If there is a precipitation of sulphide of silver, the lixiviation is continued. If there is no precipitate, and the liquor becomes only slightly discolored, he puts in some of the liquor containing the silver solution to ascertain whether there is an excess of sulphide of calcium. In this case the hyposulphite solution is discontinued and the excess of hyposulphite must be washed out with cold water. The exhaustion of the hyposulphite is distinguished by the taste. This last liquor, as it contains nothing, goes to the fresh-water tanks.

It takes from 18 to 48 hours to charge, leach, and discharge the ore, the time depending on the way the roasting has been done. Exceptionally a charge will take a longer time, sometimes as much as five or six days. In Mexico the leach-liquor is divided into two

parts, as it has been found that that coming off first contains much less of the sub-sulphates and oxychlorides of the base metals than the last, and consequently produces a purer bullion. This is not done in the West, and, when all the product must be cupelled with lead, is not necessary.

The following table gives 37 assays of the tub tailings made at the Bertrand mill during four days. They show a very low value in silver.

Tub Tail Assays from August 28th to September 1st, 1882.

No of charge.	No of furnace	No. of tub.	Value
76	2	7	$3 14
81	3	4	6 59
87	2	17	4 87
89	2	2	4 71
90	2	5	4 71
92	2	24	4 55
94	4	14	4 08
98	4	2	3 14
99	4	4	4 08
101	4	8	4.08
103	2	2	3 92
104	2	6	4 08
105	4	1	3.61
106	4	14	3 92
107	2	11	4 08
108	4	6	3 77
109	2	16	3.29
110	2	6	4 71
132	3	19	3 61
135	3	3	4.40
138	3	15	5.18
140	3	1	1 08
141	3	7	4 24
143	3	14	3.92
144	3	21	4 08
146	3	9	4 24
147	3	17	4 24
148	3	3	3 92
150	3	21	4.08
172	4	4	4.40
173	4	8	4.87
174	4	12	3 45
175	4	22	3.29
176	4	20	4.55
178	4	10	4.55
180	4	5	4.55
183	4	20	3.29

As soon as the water ceases to flow, a probe-sample is taken from three points in each tub, and they are sent to the assay office to see whether there is any silver left. The ore assays from 30 to 50 ounces; the tails should assay only about 4 ounces. These assays are being constantly made, 20 to 30 being often made in a day. If the assays show that the silver is down to from 4 to 6 ounces, the tub is discharged, if not, the ore has to be re-roasted and treated with the hyposulphite again. This rarely happens, however, for, as the

assays are constantly being made, the exact condition of the ore is known before the leaching commences.

The ore from the tubs is shovelled into cars and run out to the dump-heap at the rear end of the mill, where there is a turn-table to switch the cars into the proper track. Care has to be taken at first to see that the men do not cut the gunny-sacking in shovelling out the ore. At first, before the men are experienced, it is generally considered a necessary precaution to cover the gunny-sacking with slats from five to six inches apart, to insure that it is not cut by the shovels. When, however, the workmen are experienced, they know when they are near the bottom from the height to which they have to throw the leached ore, and they are so careful not to dig on the sacking that these slats need not be used. The sacking is very seldom cut after the men are accustomed to the work.

The following table gives the details of the leaching of the same charges, the details of which, during the roasting process, are given on page 50.

No of furnace	No. of charge.	Hours on water.	Hours on soda	Total hrs leaching.	Assay.	Chlorination.	Tub tailings.	No. of tub.
	Mixed charge.	11½	49½	61	25 44	4 08	4.71	1
2	67	9⅚	19	28⅚	42.73	3 45	3 67	16
	Mixed charge.	11⅔	25½	37⅙	28.89	8 79	4.24	17
2	68	11⅙	17	28⅙	46 18	6 12	3 92	19
2	69	10	15½	25½	27.65	5.18	3.98	23
	Mixed charge.	10⅓	20½	30⅚	44.49	6 59	4.87	24
2	70	13	29	42	27 33	3.45	3 61	3
2	71	10½	27½	38	31.42	7 38	5.18	5
2	72	10½	17	27½	26 07	6 41	5.49	7
2	73	6	23	29	27 02	3 61	3.92	9
3	74	9	15	24	29 32	6 28	3.87	22
3	75	10	7	17	26 71	4 40	6 28	21
4	88	9	20	29	31 72	2.03	6.28	15
4	94	10⅚	19	29⅚	32 99	3.61	4 08	14
4	95	14⅓	98	112⅓	35 19	9 66	6 12	13
4	96	6⅚	12	18⅚	44 49	2.98	3 67	18
4	97	8	5½	13½	29.85	6 12	4 24	20
4	98	11½	27½	39	25 75	4.40	3.14	2
4	99	9½	16	25½	31 42	4 08	4 08	4
4	100	9	8½	17½	27.96	4.01	3.61	6
4	101	6½	14½	21	25 13	3 92	4 08	8
4	102	18¾	27½	46¼	29 21	6.91	3.77	10
	Mixed charge.	6	32	38	45.25	6.59	4 87	11
	Mixed charge.	19⅓	66½	86	26 71	4.08	5 34	12

Just as soon as the tub is empty a fresh charge is put in. The 24 tubs are kept constantly working. Three men have entire charge of the tubs; they only work during the daytime. The leaching, however, is continuous, and is done by two Chinamen on each shift. They fill all the tubs, do all the testing and take the probe-samples. No other persons are allowed to touch the tubs while they are under their care. When the leaching is finished three laborers discharge the tubs, and carry the tails to the dump-heap. The head leacher is paid $2.50 and his helper from $1.00 to $1.50 per day. Fifty or sixty tons a day are leached by these two men.

6. Precipitation of the Silver.

The hyposulphite liquor containing the silver is run directly from the leaching vats to the precipitating tanks, which are 8 feet in diameter and 12 feet deep. All the solutions, except the silver liquors, are carried about the mill through wooden launders, carefully jointed with tar, and also painted on the inside with it. This is an excellent method. Iron pipes were formerly used, but they decomposed the solutions and sometimes precipitated the silver. Iron pipes lined with tar would be a better arrangement, especially in those mills whose work is not continuous. These might be ordinary steam-pipes, five inches in diameter, which are screwed together. Wooden troughs without the coating of tar were formerly used, but it was found almost impossible to keep them tight, and the penetrating nature of the hyposulphite caused a considerable loss of the reagents. Besides, when not used they shrank, which was a very great disadvantage, as they leak for some time afterwards. Troughs hollowed out of solid wood are used in some works, but they are not easily made and are more difficult to manage. The whole of this inconvenience, however, is remedied by the use of iron pipes lined with tar.

The silver liquors from all the leaching tubs are run into one precipitation vat until it is filled to within 15 to 20 inches of the top, the flow is then turned into the next vat. When this is done, the silver is thrown down at once, sulphide of calcium being added until no precipitation takes place. The solution is then agitated for some minutes to make a thorough mixture, and is then allowed to settle, and the clear liquor which is reconverted into hyposulphite of lime and soda by the sulphide of calcium is drawn off into a receiving tank on a lower level, and from there forced into a tank on the top floor, from which all the solution used runs. The reaction which takes place is

$$2NaAgS_2O_3 + 2NaCl + 10H_2O + CaS = Ag_2S + 2Na_2S_2O_3 + CaCl_2 + 10H_2O.$$

This solution in Mexico is at 25° to 30° Baumé, in the West it is much weaker.

Where various ores are treated, it requires a little time to ascertain just the quantity of sulphide to add, but when the same ores are constantly being used, it is simply measured in from a pail. There is no danger of loss, as the liquors are carefully tested. Care must be taken not to have the sulphide in excess. Only that portion of the sulphide which precipitates the silver is converted into

hyposulphite of lime; any excess of sulphide would cause a precipitation of the silver already dissolved in the solution-tanks as sulphide, which would not be dissolved by the hyposulphite and would consequently be lost in the tails. If there is an excess of sulphide some of the silver liquor must be added to neutralize it. At the Bertrand mill the sulphide of calcium added in the precipitation of the silver keeps the liquor up sufficiently with the weekly addition of about fifty pounds of hyposulphite. As soon as the clear liquors are run off other liquors are run in and precipitated, clarified and so on, for about two weeks. At the end of that time the tanks must be discharged. There are three precipitating tubs for the sulphide of silver and three for the precipitation of the base metals with the same sulphide when water is scarce.

A great deal of trouble has been experienced in the various works in pumping these solutions. In this mill an ordinary Babcock's steam-pump was used, but iron pumps were found not to work well, and steam pressure was then used to force the liquors up, which had a great many inconveniences. The simplest way is that formerly used at the Old Telegraph mine, which was to use an ordinary lifting pump made with a wooden cylinder lined with hard rubber, with a hard-rubber plunger, which cost less than $50. This pump worked perfectly for a long time without repairs.

Every fifteen days the sulphide of silver is collected. The arrangement is made to have the whole mill cleaned up at one time. To do this the sulphide in the bottom of the tanks is stirred vigorously until the material is in the state of a thin mud. It is then drawn off from the bottom of the tank and run over cloth filters. These filters consist of a series of frames about 2½ feet square, over which sacking is securely fastened. There are 30 of these frames, 3 in a row, built on the same table, which is surrounded by a rim 3 inches high. Underneath the table is an inclined trough which carries all the liquors to the collecting vat. The turbid liquor from the precipitating vat is run on to this table and flows from one sacking to the other. The solution drains through and the pasty sulphide remains on the sacking. This operation is constantly repeated until the sulphide of silver has accumulated in considerable quantity on the sacking. It is then washed with clear water to remove the excess of sulphide of calcium until it is perfectly sweet. It is then left to dry. In drying, it cracks in every direction. It is shovelled into a car and carried to the reverberatory furnace to dry and roast. As there is a considerable amount of water in the pasty mass, it is

in some works collected in canvas bags and the water squeezed out with a press before it goes to the furnace.

7. Roasting the Sulphide of Silver and Melting for Bullion.

The sulphide of silver is now ready to be dried in a reverberatory furnace, as it still contains some water. The heat must be quite low at first, only just enough being used to burn off the sulphur. It can only be increased very slowly at first for fear of melting the sulphides. It is roasted until most of the sulphur is driven off, and the heat is then raised to as high a temperature as possible without melting. When sulphur is scarce the sulphide is heated in a retort, and the sulphur condensed to be used over again. Mr. O. H. Aaron proposes to take the freshly precipitated sulphide and boil it, adding freshly slacked lime in small quantities at a time to the liquor, which is kept constantly agitated. When this is carefully done the poly-sulphide of calcium will be formed much more quickly than by the direct action of the sulphur, and most of the sulphur in the sulphide of silver will be regained. The liquor is decanted, and the residue is dried and roasted. After roasting, it is a gray mass composed almost entirely of metallic silver.

Formerly the roasted silver was melted in graphite crucibles, but this was found to be too expensive. It is now cupelled with the addition of lead in an English cupel. The litharges are rich in silver and are all reduced to form the lead for the next cupellation. From the cupels it is cast into bricks and is between 800 and 900 fine. No attempt is made to make it finer, as it is found cheaper to sell it than it is to refine it.

It must not be taken for granted that the bullion produced from this process is necessarily purer than that produced by any other. The contrary is likely to be true. If the ore contains a large quantity of base metals, particularly lead, these would be only partially affected by amalgamation, while most of the lead contained in the ore will be likely to be found in the bullion made by leaching. The reason for this is that while all that portion of the lead which is in the form of chloride may be leached out, and, by the judicious arrangement described, the other metals can be separated, none of the lead present as sulphate will be attacked by the water, while most of it will be dissolved by the hyposulphite and will be precipitated by the sulphide, thus using a larger amount of the reagent, and being a direct source of loss. This, however, except in very poor ores, is not a grave inconvenience. In other respects the bullion is likely to be

purer. The loss is practically very small. The outlay for chemicals is also very small, as they are constantly regenerated, and the same water can be used over and over again. The amount of necessary loss in the tails will depend, other things being equal, on the price of labor. It is very easy to ascertain this by making a daily clean up, or making a time assay, to ascertain exactly how much is being extracted in a given time. The assay shows that 85 per cent. of the silver in the chloridized ore is saved. From 50 to 60 tons are easily treated in the twenty-four hours. The average product of the Bertrand mill is from $30,000 to $40,000 per month; that of the Triumfo works is from $50,000 to $60,000 per month.

There are 60 men in all employed in the Bertrand mill. The following table gives the special occupation of each of these men and the wages they receive.

MEN REQUIRED TO RUN THE BERTRAND MILL DURING 24 HOURS.

Roasters—furnace men,	2 @ $4 00	$8 00
" —feeders,	2 @ 3 00	6 00
Driers and rollers,	10 @ 3 00	30 00
Cooling-floor,	6 @ 3 00	18 00
Leaching-floor, Chinamen,	2 @ 2 50	5 00
" " "	3 @ 1 50	4 50
Rock breakers,	2 @ 3 00	6 00
Flue cleaners,	4 @ 1 50	6 00
Blacksmith,	1 @ 6 00	6 00
" helper,	1 @ 3 00	3 00
Carpenters,	2 @ 5 00	10 00
Engineer,	1 @ 5 00	5 00
"	1 @ 4 00	4 00
Fireman,	1 @ 2 50	2 50
Assayer,	1 @ 5 00	5 00
Lamp cleaner,	1 @ 1 50	1 50
Foreman,	1 @ 6 00	6 00
"	1 @ 5 00	5 00
Office helper,	1 @ 1 50	1 50
General helper,	1 @ 3 00	3 00
Watchman,	1 @ 3 00	3 00
Woodmen, Chinamen,	3 @ 1 50	4 50
" "	1 @ 3 00	3 00
		$146 50

All the charging and discharging and leaching is done by four Chinamen and three Irishmen. The total cost of milling the ore is $6.50 per ton. The cost of mining and delivering the ore at the mill is about $2.50, which makes the total cost about $9.00 per ton of actual expense on each ton of 30-ounce ore.

COPPER SLIME TREATMENT.

BY F. G. COGGIN, LAKE LINDEN, MICH.

"If you could only get that motion into a machine," said a gentleman, as he watched the process of making a "van" on a shovel, and saw the copper roll up to the highest point, "it would beat the world for slime-dressing." This idea has led to many an effort to get into a machine that peculiar motion, called the "vanning motion;" and so cams, eccentrics, eccentric gears, levers, bell-cranks, toggle-joints, links, springs, etc., have been brought into requisition, while a contribution has been laid upon all the conceivable motions, rolling, tumbling, swinging, jerking, tossing, dropping, tripping, intermittent, regular and irregular, or a combination of some of them, to which have been added percussion, concussion, and more discussion —all in a vain attempt to combine in a single machine the consecutive motions of the shovel, in washing, flowing, and tossing the van. The Patent Office Reports, and the various mills of the country, show, as a result of this, a lot of gimcracks, most of which never went beyond a first trial, finding their way to the scrap-heap. Others still running might as well be there; while some have considerable merit for dressing other and richer sands than copper.

It does look tempting to see that clean edge of copper climbing up the shovel-blade; but those who have seen in it such visions of large fortunes have not considered the time it takes to make a van, compared with the small quantity treated upon the shovel; and this points to the reason for the failure of all that class of machines called "vanning machines," when used for dressing copper slimes, namely, a lack of capacity. The writer has come to this conclusion through an experience with the Rittinger side percussion-table of the most improved make, sent from Germany to the Calumet and Hecla Mining Company, and with the Ellenbecker tables, used by the same company, both of which are good types of that class of machines. In both of these machines, the tables are suspended by rods which allow them to swing, and they can also be adjusted for the purpose of varying the inclination of the table. In the Rittinger machine, the motion of the table is at a right angle to the flow of the slime, being produced by a wiper-cam which throws the table against a spring, which throws it quickly back against a stop, the percussion throwing up the mineral. In the Ellenbecker table, the motion is

with the flow of the slime, and has a quick return, produced by the use of eccentric gears, the idea of the latter being taken from the valve-gear of the old Ball steam stamp. The estimated capacity of the Rittinger machine was eight tons per twenty-four hours; but it would not properly treat over five tons in that time, or about fifty pounds per square foot of floor space taken up by the machine. The Ellenbecker table has about the same capacity. The assay of slime was about 1.3 per cent.; that of the tails, 0.97 per cent. This is not considered very good work.

Of other machines for dressing slimes, the best known are the fixed round buddle and the revolving table; perhaps the Frue vanner may be included in this class of machines, although, having had no experience with the latter, I can say nothing with reference to its capabilities. The principle governing the concentration upon both the former is the same. In the one, the table is fixed while the distributing and washing apparatus revolves. In the other, the table revolves while the rest of the apparatus is fixed. The revolving table is the most largely used in this country, the design of Mr. Evans, of the Atlantic Mine, Michigan, being almost exclusively used in the copper mills of Upper Michigan. This differs little from the German revolving table, except that it has a "dead-head" at the centre from 6 to 8 feet in diameter, one-half of which is used for distributing the slime, the other half being used for clear water. The outer rim of the latter is a spiral, the surface broadening toward that point where the concentration is washed off. I have also made this rim in steps of from six to ten inches, with good results.

It may be said that this dead-head takes up a large area from the table; but this area, being immediately around the centre of the table, is of little or no value for settlement; for the current of the slime delivered at the centre is too rapid for settlement to take place until it has spread itself over an area equal to that of the dead-head, the office of which is to spread the slime moderately and evenly upon the revolving table.

In a paper read before the Institute at its last meeting in Boston, by Mr. R. P. Rothwell, it was stated that in the German dressing-works the revolving tables were being superseded by the Linkenbach fixed round buddle, for the apparent reason that the revolving tables, if over 17 feet in diameter, were expensive to build, were unwieldy, and necessitated more operations to concentrate. Some two years ago, a complete set of drawings of the Linkenbach buddle, with a set of irons for the same, were sent to the Calumet and Hecla Mining

Company with a view to their introduction, the German estimate of the cost of a single buddle being \$717. A thorough examination of the drawings, with their description, and of the irons sent, compared with the practical workings, etc., of the Evans table, led to the adoption of the latter for several reasons:

1. The cost of the Evans table, with only moderate facilities for its construction, will not exceed \$225. The fixed buddle, with the inventor's estimate of the material and labor at prices paid for such in this section, would cost at least four times as much, or \$900. This, for the number of tables required by the Calumet and Hecla Company to properly dress its slimes, would make a difference in first cost of \$20,000.

2. The fixed buddle, with its revolving apparatus, is more complicated than the Evans table, and therefore more liable to get out of order. If there was anything to compensate for the extra cost of the fixed buddle, it would not matter; but there does not seem to be anything. The capacity of the two machines seems to be about alike; that is, from 12 to 13 tons of slime (weighed dry) per twenty-four hours. This refers to a table 20 feet in diameter, as compared with those referred to by Mr. Rothwell, said to be about 26 feet in diameter. Comparing the capacity of the Evans table with that of the Rittinger percussion-table, per square foot of floor space taken up, the former gives 96 pounds of slimes against 50 pounds by the latter, a gain in favor of the Evans table, or round buddle, of 92 per cent. The water required by the buddle and table does not seem to vary much. Taking Mr. Rothwell's figures, the minimum, 5½ tons of slime in ten hours with 19 gallons per minute, gives about 2100 gallons of water to the ton of sand. Experiments with the Evans table give about 2000 gallons to the ton. There is no difficulty in making an Evans table 20 feet in diameter or more without making it unwieldly, and at a cost specified above. Nor is there any difficulty in putting one table above another, either on the same shaft, to be driven together, or on a framework, to be driven independently; and in either case, the power to drive them is of no consequence, as the table revolves upon a steel step 1¼ inches in diameter, and a child could turn one even while loaded. With respect to the surface, those used in Upper Michigan being made of wood, have a wood surface which works very well. One table has a canvas surface, which is said to work well for certain grades of copper. I think that the best surface for the peculiar stuff to be treated can only be determined by experiment. I understand that in Germany

much experimenting has been done in this line without fixing upon any one surface suitable to all materials and conditions; marble, slate, cement, wood, rubber, canvas, etc., each having been found best under as many conditions. This holds true with respect to nearly all machines, and many a machine that is doing its best in one place is condemned in another because it will not give as good results, under varying conditions, when perhaps only a slight modification in the machine itself was needed. As well condemn the saw that will not easily split the board it has so easily cut in two.

As to sizing the material for the table, I am not yet convinced as to the necessity for it, in copper dressing. It seems to me that the necessity for it is brought about only by poor separation at the jigs. With the separators usually used, the trouble has been that if enough hydraulic is used to keep the jigs free from slime, it carries over the tail of the separator a great deal of sand that should remain on the jigs, and which is detrimental to good work on the table. This is true of all separators where the excess of the hydraulic has to pass up through a narrow aperture, through which also the mineral must fall. I suppose as much effort has been made to secure a perfect separation as in any other line in mineral washing. Many have worked with a wrong end in view, and I may add in hydraulic separation, an impossible end, namely, a perfect sizing of the particles. Not only that, but for jigging purposes, a perfect sizing is not desirable, especially with the coarser sands; but as this is not within the province of slime-treatment, I will not stop to discuss it.

However necessary it may be to classify the slimes, before going to the tables, it is certainly necessary to first get all the slime free from the sand that should remain on the jigs. I am glad to announce that this has at last been accomplished with the separator recently adopted by the Calumet and Hecla Company, and secured by letters patent. In the usual method of washing and separation, where the mineral has to drop through a narrow aperture, against a rapid and direct current of water, if the current is strong enough to keep back the heaviest particles of slime, it will also keep back the lighter particles of sand, suitable only for the jigs. Moreover, a great deal of the slime clings to the larger particles of the sand, and must be washed off in the separator if good work is desired. Heretofore I have seen no separator that would do this. In the new separator alluded to, the hydraulic is brought into each compartment from behind, by a pipe whose discharge is opposite to and near the spigot. Over this pipe and spigot is placed an adjustable shield

which controls the hydraulic so that it reacts with a uniform current against the mineral seeking egress through the spigot, effectually washing all the slime from the particles suitable for the jig. This process, being repeated at each spigot as far as carried for the jigs, carries away the slime, leaving the jig-tails perfectly clear, while the tables reveal the fact that no sand suitable for jigging has been carried over. This is a very important part of slime-treatment. These results are accomplished with from twenty to twenty-five per cent. less water, which very much facilitates the subsequent treatment of the slime.

Recent trials contrasting the new separator with the old V-shaped separator, with reference to the quantity of hydraulic required when both were doing the *same* work in separating the slimes, showed a decrease of fifty per cent. in favor of the new separator, which at the same time was giving much the best classification for jigging purposes.

This separator was more fully described in a paper read before the Institute at its last meeting in Boston, by Professor Robert H. Richards, of the Institute of Technology in Boston. The slimes of the Calumet and Hecla assay from 1.2 to 1.3 per cent., the tails of the Evans table going away at about 0.65 per cent.—results that are very good, considering that no free copper is found in the tailings. No matter how finely subdivided these sands may be, the particles still contain a finer particle of copper.

Thanks are due to the Calumet and Hecla Mining Company, which has been so liberal in its search for the best appliances, and which has seconded the efforts of those out of whose research and experience these results have come.

THE GEOLOGICAL POSITION OF THE PHILADELPHIA GNEISSES.

BY PROF. C. H. HITCHCOCK, STATE GEOLOGIST, HANOVER, N. H.

REPORT C^6 of the Second Geological Survey of Pennsylvania, by Charles E. Hall, describes the rocks of the Philadelphia belt, and sets forth conclusions widely different from those derived by others from the study of similar strata along the same stratigraphical line.

Mr. Hall classifies these rocks into three groups: First, the Philadelphia schists and gneisses, well shown within the city limits and

dipping northerly; second, the Manayunk schists and gneisses, similarly situated; third, the Chestnut Hill schists, serpentines, and gneisses, in synclinal attitude; all three probably amounting to 20,000 feet in thickness. A fourth crystalline band is to be seen north of Chestnut Hill, which Prof. H. D. Rogers called the "third belt," and supposed it to be the equivalent of Hall's Philadelphia and Manayunk groups, on the opposite side of a synclinal. Inasmuch as the lithology of the two series is very different, it would seem that Mr. Hall is correct in regarding them as of diverse age. It would follow necessarily from the agreement of both observers as to the dips, that a profound fault must exist between the Chestnut Hill schists and the "third belt." The "third belt" is overlaid unconformably by a quartzite, referred to the Potsdam, whose constituents seem to have been mainly derived from this hornblendic gneiss, rightly called Laurentian. In endeavoring to assign the Philadelphia groups to their proper horizon, our author finds no place for them lower down than the Devonian—forgetting that he has not stated what groups should occupy the place of this unconformity. My studies elsewhere lead me to refer these Philadelphia gneisses to the Montalban system of New Hampshire, which corresponds in time to the admitted stratigraphical break between the Laurentian and Potsdam. There is nothing in any of the facts presented in the report which cannot be explained better by the adoption of this view; and it looks to us as if Mr. Hall did not properly keep in mind the presence of the Chestnut Hill fault. The apparent dip of the Potsdam beneath the mica schists has no significance.

Prof. Lesley, in commenting upon Mr. Hall's conclusions, thinks "we can accept the Palæozoic age of the Philadelphia gneisses with a moderately reserved confidence:" * and refers to his own impressions of thirty years ago, obtained from studies in New England, as confirmatory. In the original paper, † he speaks of these opinions as "conjectures," based upon the supposed synclinal structure of the White Mountains, as observed along the Grand Trunk Railway and at Waterville. The New Hampshire Geological Survey has shown satisfactorily that the structure of these mountains is altogether different. Besides this, Prof. Lesley has himself given us a contrary opinion in his own writings, and in spite of his own later remarks in C^6, posterity will not fail to rank him as one of the strongest advocates of the Eozoic age of the Atlantic crystalline rocks. He had

* Report C^6, page xi.

† Proc. Acad. Nat. Sci., Phila., 1860, p. 363.

just prepared an elaborate topographical map of Eastern America for the President of the Grand Trunk Railway, for the purpose of showing the intimate connection existing between the topography and geology of a country. He says, after the first inspection of the completed work, "I was surprised at the beauty of the whole representation, now for the first time made to the eye. The correlation of parts was very fine, in a geological sense. The plateau of the coal, commencing in Alabama and cut off square by the Hudson, contrasted strongly with the essentially unbroken run of the Quebec group and Laurentian system, from Georgia to the extreme east end of Canada; while the open valley of the Lower Silurian, everywhere keeping two systems apart, was most remarkable."* It is not possible to state more forcibly the topographical argument for the unity of the crystalline series from Alabama to Quebec; and it is consequently very strange to find this admirable generalization, derived from a survey of the whole field, laid aside for an earlier crude conjecture. Philadelphia is situated at the largest depression in the Atlantic range, and is hence badly located for the study of these complicated questions of age.

In confirmation of the Eozoic age of the crystalline highland series, we find the ancient primordial sea-beach continuously skirting its western edge. In Vermont, New York, Pennsylvania, Virginia, and Tennessee, observers agree in ascribing the source of the grains of sand in this quartzite to the crystalline rocks to the southeast—thus establishing the doctrine of the existence of dry land in pre-Cambrian times in the Atlantic district. This has lately been conceded for Southern Vermont and New York by Prof. J. D. Dana. It is also universally agreed that the entire Appalachian district has been gradually developed by successive additions to this ancient primordial beach. Hence, there must have been a very large area of land to the southeast, before the Potsdam age, both to furnish a floor for the support of the Palæozoic sediments and for their origin. The 40,000 feet of strata in Pennsylvania did not come from the narrow "third belt" of Rogers. The Philadelphia gneisses and many thousand square miles of other crystalline rocks must then have stood above the sea-level and furnished the pabulum for the rapidly growing continent.

If we look on this crystalline area north of Pennsylvania, we shall find fossiliferous representatives of all the leading Palæozoic groups of rocks, resting upon the schists. The Cambrian occurs with *Para-*

* Trans. Amer Phil. Soc, vol. xiii., N. S, p. 307, 1866.

doxides, *Conocoryphe*, and *Lingula* in Southeast Massachusetts, and with a much larger fauna in New Brunswick. Silurian groups occupy large areas through Massachusetts and Vermont just west of Connecticut River. The Niagara is now known at several points east of the Connecticut in New Hampshire, almost under the shadow of the White Mountains. The Oriskany is much thicker in Maine than elsewhere in the country, and the same may be true of the associated Lower Helderberg. The same are distributed more or less commonly over Northern New Brunswick. The Upper Helderberg is recognized at Bernardston, Massachusetts, Memphremagog Lake in Canada, and in Maine. The nearest locality to Pennsylvania is evidenced by middle and lower Devonian fossils found in pebbles of cretaceous sandstone in the clay district of Middle New Jersey. Prof. Cook says their source "must be looked for to the southeast of the present strata."*

The carboniferous area of New England contains more square miles than the anthracite fields of Pennsylvania, and has yielded numerous specimens of fossil plants for the museums. Many other Palæozoic outcrops would be displayed, could we get access to the submerged part of the continent between New Jersey and the Great Banks of Newfoundland. Wherever found, these strata are well characterized, are not metamorphosed beyond recognition, and when thoroughly examined are clearly distinct from the crystalline floors supporting them. We cannot resist the growing conviction that all the thoroughly crystalline series of the Atlantic region are of Eozoic age, while traversed by large eruptive areas of granitic character. But these crystalline schists are grouped into terrains easily separable into successive periods of growth. We easily recognize a basal group of porphyritic gneisses; secondly, talcose and biotitic gneisses; thirdly, the mixed muscovite and biotite-schists characteristic both of the White Mountain and Philadelphia areas; fourthly, the Huronian. Subsequently, there were other deposits of mica-schists, frequently confounded with the Montalban, and so fresh in appearance that some authors regard them as belonging to some unknown Palæozoic period. When geologists really attempt the study of the crystallines, they will find abundant opportunity for prolonged and elaborate investigations.

Exceptions to Mr. Hall's views have already been taken in public by Profs. P. Frazer, H. Carvill Lewis, and Mr. T. D. Rand.

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* Report on the Clay Deposits, p. 30.

Discussion.

Dr. Persifor Frazer, Philadelphia: It would have aided Pro fessor Hitchcock in understanding all the difficulties which bese this region, if he had been personally on the ground. He would the see that these difficulties are inherent in the case, and have been ex perienced, as he mentions, not only to the northeast but throughou the whole extent of the Atlantic range. If I correctly understood Professor Hitchcock's remarks, they were directed, first, to showing that Mr. Hall's reason for supposing that the ridge north of the Chest nut Hill schists was composed of the lowest rocks (*i. e.*, because they had been recognized as Laurentian in New Jersey) was not a valid one, and that the schists to the north and south of that ridge might be connected in a synclinal. A few moment's inspection of the ridge, where it is cut by the Schuylkill, would have dissipated this notion, as its anticlinal character is apparent, and it is needless to introduce arguments against a structure which would place an anti-clinal in the lap of a synclinal.

I agree with Professor Hitchcock as to the pre-Palæozoic character of the Philadelphia gneisses, and of the south Valley Hill schists, and also in profound faults which occur on both sides of the Laurentian ridge and in general parallel with its axis. One of these is with little doubt situated close to the Chester Valley, and forms the southern border of the latter throughout the entire county. It is possible, also, that a fault exists south of this Laurentian mass in Philadelphia County, but, if my surmise be correct that the Buck Ridge is a prolongation of the Tocquan anticlinal, which crosses the Susquehanna at the creek of that name, then this fault does not extend southward and westward in a line parallel to the axis of the anticlinal, because on each flank of this anticlinal are regularly deposited thousands of feet of Huronian measures, the axis, according to my theory, sinking towards the southwest, and being represented on the Susquehanna by more modern rocks than on the Schuylkill. It may be that this fault is connected with the obscure structure in the neighborhood of Fishing Creek.

It has been stated that H. D. Rogers supposed the three belts of the southern gneiss-zone to represent three separate horizons. The following language of Professor Rogers's Final Report (pp. 79 and 80) will set this question at rest:

"If now we review these interesting features"—(of the southern zone),—"we can hardly resist the conclusion that in the three belts passed over by our section there are really but two groups of rocks,

a lower and a higher, and that the entire zone, viewed broadly, constitutes but one wide synclinal wave or basin, the harder feldspathic or hornblendic gneiss dipping northward throughout the whole southern belt or outcrop, and reappearing in steep and multiplied contortions on the other side of the trough, and the upper or more micaceous groups of rocks filling the synclinal centre of the trough, and compressed into the lesser foldings which it exhibits by the lateral force of the wide crust undulations within which it has been caught and folded."

T. D. RAND, Philadelphia: I have a word to say in regard to the Chester Valley. There exists on the south side of the valley, as on the north, a body of sandstone, quite distinct in some places, not through its entire length, but distinct in several localities. I do not say that the sandstone is Potsdam; I do not profess to be geologist enough to know. But that belt of sandstone occurring just where the Potsdam ought to be, if the valley is synclinal, opposite its location on the north side, seems for some reason to have been ignored.

THE DETERMINATION OF MANGANESE IN SPIEGEL, FERROMANGANESE, STEEL, Etc.

BY MAGNUS TROILIUS, MIDVALE STEEL WORKS, NICETOWN, PHILADELPHIA.

THE importance of having methods for the rapid and accurate determination of manganese in modern steel manufacture cannot be overestimated.

The method adopted in the laboratory of the Midvale Steel Works is very satisfactory, and I think it will be of interest to some of the members to give a description of it.

Before giving the more detailed account of the manipulations, a review of some well-known methods and chemical facts may not be out of place. The "bromine and ammonia" process, as fully described in the tenth volume of the *Transactions* of this Institute, was certainly an improvement on the methods in which fixed alkaline salts were used, as these gave invariably too high results, as generally carried out. But the separation of all the iron before the manganese was, in both methods, a source of great inconvenience and delay.

The discovery of the insolubility in strong nitric acid of manganese dioxide (MnO_2), has been of great value, but the modes of determining manganese based on this discovery are very different, and the opinions as to the results somewhat conflicting.

I hope that the statements given in this paper may serve to throw some more light on the subject, and remove unnecessary prejudice against one of the most remarkable improvements in modern steel-chemistry.

When a solution of iron in nitric acid (1.42 sp. gr.) is boiled with crystals of potassium chlorate, all the manganese present is precipitated as MnO_2, this compound being almost entirely insoluble in hot acid, and completely so in the cold acid. Thus, if, after boiling, cold strong acid be added, complete precipitation is secured, and the MnO_2, contaminated with a little oxide of iron, and small amounts of other oxides that may happen to be present, can be filtered off, purified by basic acetates, and determined by precipitation in ammoniacal solution with bromine, igniting and weighing as Mn_3O_4, as in the old bromine and ammonia process.

This, indeed, was the first method used at Midvale, after abandoning the cumbrous basic-acetate processes. But even this proved to be too slow a procedure, and a volumetric method suggested itself as the nearest solution of the problem.

Under the supposition that all the manganese is precipitated as binoxide by nitric acid and potassium chlorate, I added to the precipitate, after separating it as usual, a measured quantity of standardized ferrous sulphate solution, and titrated the amount left unoxidized, using potassium bichromate as standard oxidizing liquid. I expected to find the results by this process slightly higher than by the previous gravimetric process, owing to a slight loss in the latter in the basic acetate, and on the sides of the beaker, when precipitating the manganese by bromine in ammoniacal solution. The results confirmed this expectation, and thus a practical proof was at the same time obtained that the manganese is really precipitated as MnO_2, and not as some lower oxide.

That the manganese would be completely separated as dioxide by potassium chlorate and nitric acid might, moreover, be anticipated by considering the following facts:

1. If manganese dioxide be boiled with potassium hydrate and potassium chlorate, it will be converted into potassium permanganate, easily extracted with water after evaporation to dryness.

2. Further, if potassium permanganate be boiled with *strong* nitric acid, all the manganese will separate as dioxide, insoluble in the excess of nitric acid; but, if weak acid be used, this reaction will not take place.

Now, when precipitating the manganese by potassium chlorate in a nitric acid solution, as described, a combination of these two reactions does evidently take place. A hot nitric acid solution of manganese is in itself in a highly oxidizable condition, and on addition of the powerful oxidizer, potassium chlorate, it is brought to its maximum of oxidation, viz., permanganic acid. This can easily be seen if water be added while there are still crystals of potassium chlorate left undecomposed. The well-known pink color will then distinctly appear. But as there is an excess of strong nitric acid present, the above reaction (No. 2) will take place, and all the manganese will be brought down as dioxide.

How the manganese, in view of the facts referred to, could reach a lower state of oxidation than MnO_2, as has been erroneously supposed by some, is not easy to see. The whole tendency in this process is to convert the manganese into its highest state of oxidation, which would be permanent but for the existence of the compound, MnO_2, insoluble in nitric acid.

In fact, the principal precaution in the potassium chlorate and nitric acid process is to avoid loss through formation of permanganate of potash. This precaution is observed by cooling with strong acid after precipitation, and in washing with strong nitric acid until all the chlorate of potash has been thoroughly washed out.

Volumetric Determination of Manganese.

For spiegeleisen, 0.2 gram; for ferromanganese, 0.1 gram; and for steels, 5 grams, are taken for the test. Spiegel and ferromanganese are dissolved in dilute nitric acid, and afterwards boiled with the strong acid; but steels are dissolved in hydrochloric acid, the solution evaporated to moderate dryness, the mass dissolved in strong nitric acid, and boiled until the excess of hydrochloric acid has been removed.

To the boiling solution in strong nitric acid small crystals of potassium chlorate are gradually added. Yellow fumes are given off, and soon a brown precipitate appears. A few more crystals are then added, and boiling is continued for a few minutes. The solution should not be too concentrated when adding the potassium chlorate, as then violent explosions will occur (ClO_2). Add an excess of cold strong nitric acid, allow to settle, and filter on asbestos, by aid of the suc-

tion pump, in a glass tube. Wash with strong nitric acid and finally with cold water. Blow the contents of the glass tube back into the beaker in which the precipitate was made, and add from a pipette 100 c.c. of a sulphuric acid solution of ferrous sulphate containing about 10 grams of salt (or 2 grams of iron) in 1 liter. Run in boiling water, and stir until no small lumps of precipitate are visible. Transfer the solution and the asbestos to a large porcelain dish, and titrate with standard potassium bichromate (14 grams of $K_2Cr_2O_7$ to 1 liter). The end reaction is most delicately observed by mixing drops from the solution with small drops of a solution of potassium ferricyanide ($K_6Cy_{12}Fe_2$) on a porcelain plate: The solution of $K_6Cy_{12}Fe_2$ will be of proper strength when a small crystal, of the size of a pea, is dissolved in 100 c.c. of water.

The solution of the bichromate is standardized by means of ammonio-ferrous sulphate $\left(\begin{smallmatrix}(NH_4)_2\\ Fe\end{smallmatrix}\right) 2SO_4 + 6H_2O$, containing one-seventh part of iron. The iron standard multiplied by .491 gives the manganese standard, according to the following formulas:

1. $MnO_2 + 2FeO = MnO + Fe_2O_3$.

2. $6FeSO_4 + K_2Cr_2O_7 + 7H_2SO_4 = 3(Fe_23SO_4) + K_2SO_4 + Cr_23SO_4 + 7H_2O$.

A determination of this kind can be easily completed in two hours. In the case of spiegel and ferromanganese, however, still more rapid results may be obtained by using an indirect method, determining the iron by standard bichromate, and deducting for silicon, phosphorus, copper, carbon, etc., a figure obtained from Professor Ledebur's table:

For iron, less than 20 per cent., deduct 7.5 per cent.

For iron, 20 to 45 per cent., deduct 6.5 per cent.

For iron, 45 to 65 per cent., deduct 6.0 per cent.

For iron, 65 per cent. upwards, deduct 5.5 per cent.

This gives the manganese, by difference, within .5 per cent., and this is, for all practical purposes, sufficient. As the direct method, however, can be carried out in a very short time, both methods should always be used for control.

If metals, such as lead, cobalt, etc., be present when precipitating the manganese with potassium chlorate in nitric acid, too high results may be obtained, owing to the formation of the higher oxides of these metals. But these metals do not generally occur in such quantities as to cause any serious error, not even in the ores used for the manufacture of spiegel and ferromanganese.

The bichromate is preferable to the permanganate for iron determinations generally, and for the manganese determination just described the permanganate is inadmissible, except with special precautions, particularly when oxalic acid is used instead of ferrous sulphate.

The permanganate, being an excessively powerful oxidizer, will be decolorized by any organic matter that may have come from the asbestos or other sources, while the bichromate does not alter from this cause. This fact is very apparent when a sulphuric-acid solution of oxalic acid is titrated with permanganate at a temperature of about 70° Cent. Oxalic acid is best titrated in nitric-acid solution at a temperature of 60°, but this could not be applied for the manganese determination in question, although it is very suitable for lime determinations in ores (Eggertz).

The bichromate solution can be used even for titrating hot hydrochloric acid solutions, although the end reaction in this case is not so distinct as when a hot sulphuric acid solution, which is less oxidizable, is used. In a sulphuric acid solution the titration proceeds with ease and delicacy, the color becoming more and more light-blue on the porcelain plate, until the last $\frac{1}{10}$ c.c. of the bichromate produces a decided *brownish* tint.

The bichromate has also the advantage of being a cleaner liquid, not liable to stain, and of being easier to keep than the permanganate. It is possible, it is true, to preserve the permanganate standard solution, so that it does not change, for a long time, but this requires greater precautions than the bichromate. Another great advantage in using the bichromate is that one may use a small spout with pinch-cock and rubber-tubing on the burette, instead of the glass stopcock which is necessary for the permanganate. Finally, where numerous manganese determinations have to be made, the economy of using ferrous-sulphate and bichromate instead of oxalic acid and permanganate will soon be apparent.

Bichromate titrations are rapidly replacing permanganate titrations on the European continent. In England they have long been held in preference. I may also mention that of all chemists that I have met in Europe, the "bichromate men" have been experts on the permanganate as well, while the "permanganate men" have known but little about the bichromate method.

In conclusion, I add a table showing comparative results obtained by different methods:

	GRAVIMETRIC.			VOLUMETRIC.	
	Basic Acetate and Bromine and Ammonia process. Per cent of manganese.	Eggertz's fixed alkali method with acid wash water. Per cent. of manganese.	HNO_3 + $KClO_3$ and Bromine and Ammonia. Per cent. of manganese.	HNO_3 + $KClO_3$ and Bichromate Per cent. of manganese	Indirect, Bichrom. and Ledebur's Table. Per cent of manganese
Ferromanganese,	....	....	60.331	60 230	....
"	73.31	....	....	73.540	73.30
Spiegel,	{ 10 094 9.986	....	....	10.144	....
Steel,	.62	.65	....	.611	....
"	....	....	{ 1.379 1.375	1.432	....
Pig-iron,	1.72	....	....	1.77	....
Steel,	....	....	.521	.531	....
"	....	....	1.05	{ 1.06 1.06 1.064	....
"	....	....	.456	.467	....
"	....	....	.552	{ .558 .571 .561	....
"	....	....	.331	.351	....
"	....	....	.461	.480	....

NOTE.—October 27th, 1883. Since the above was written I have made further researches on the method above given, and find that the nitric acid used for washing the MnO_2 precipitate must be perfectly free from nitrous acid (N_2O_3), as otherwise the MnO_2 will be converted to a manganous salt.

When precipitating the Mn in spiegel and ferromanganese (in the latter case particularly), it is well to add an excess of pure ferric nitrate, and to boil with HNO_3 and $KClO_3$ repeatedly. The presence of a ferric nitrate aids the complete separation of Mn as MnO_2.

We have made an immense number of determinations by the method in question at Midvale, and it works well. But the above points ought to be in the paper, to make the description more complete.

THE VOLUMETRIC DETERMINATION OF MANGANESE.

BY J. B. MACKINTOSH, E.M., NEW YORK CITY.

IN a recent paper read before the Institute on this subject, Mr. G. C. Stone advances the theory that the precipitate obtained in Williams's volumetric process,* by treating the boiling nitric acid solution of a manganese salt with potassic chlorate, is not pure MnO_2, but approximates more closely to the composition $10MnO_2+MnO$.

As the value of the process and the accuracy of our results would depend on whether this was the fact or not, it has seemed to me, and to my associates, Messrs. Beebe and Colby, that it would be of importance to ascertain the composition of this precipitate, and to that end the following series of experiments has been undertaken.

These experiments have all been based on the considerations:

1. That potassic permanganate has an oxidizing power equivalent to five atoms of oxygen for every two of manganese:

$$K_2Mn_2O_8 = K_2O.2MnO.O_5.$$

2. That the same amount of manganese in the state of binoxide has an oxidizing power equivalent to two atoms of oxygen:

$$2MnO_2 = 2MnO.O_2.$$

If, then, we take a solution of permanganate of unknown strength, and reduce it to binoxide, the oxidizing power of the binoxide formed will be equal to that of two-fifths the quantity of the permanganate solution originally taken. While, if the precipitate obtained should not be binoxide, but an indefinite or definite mixture of bin- and mon- oxides, then, from its equivalent oxidizing power, we can calculate its composition.

The analyses were conducted in the following manner. The amount of permanganate taken was decomposed with hydrochloric acid, and concentrated to expel the excess of water. Sufficient excess of nitric acid was now added, and the solution was boiled until all the hydrochloric acid was destroyed. The manganese was then precipitated by potassic chlorate; and, after standing some time to cool—a pre-

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* Transactions, vol. x., page 100.

caution which we consider of importance—the precipitate was filtered out through asbestos, washed with nitric acid, and then with water, and when perfectly clean was treated with a volume of oxalic acid, whose equivalent in permanganate was known, a few cubic centimeters of sulphuric acid being also added. The excess of oxalic acid was then estimated by permanganate, and the difference between this amount and the equivalent of the whole amount of oxalic taken gave the oxidizing power of the precipitate.

To save multiplication of figures we will only give the results obtained:

$K_2Mn_2O_8$ used.	Oxidizing power of precipitate in terms of $K_2Mn_2O_8$.	Theoretical for. MnO_2.	Apparent per cent of theoretical.	Corrected per cent for burette error.
c c	c c.	c c.		
45	17.80	18	98.89	99.37
35	13.93	14	99.50	100.07
25	9.90	10	99 00	99.86
15	5 96	6	99.33	100.67

Average true per cent., 99.99

The precipitation in the above results was effected by successive alternate additions of potassic chlorate and nitric acid, until no further formation of yellow fumes was observed. Shortly after first employing the method, we noticed that the reaction was seldom complete when potassic chlorate was added during one period only, and that if, after the apparent completion of the reaction, as marked by the explosive cessation of yellow fumes, more nitric acid was added, and then a fresh portion of potassic chlorate, that the yellow fumes would reappear, again to disappear with the characteristic puff. On this account it is necessary, in employing this method, to add alternate amounts of nitric acid and potassic chlorate, until no further effect is produced; and, if this precaution is not observed, the results will almost invariably be low.

The next series of experiments was made to illustrate this point, and to determine the amount of error which would be incurred by exactly following the directions given by Messrs. Ford* and Williams in their respective papers, namely, by adding potassic chlorate during one period only, and boiling till the apparent cessation of the reaction. The results obtained were as follows:

* Transactions, vol. ix., page 397.

$K_2Mn_2O_8$ used.	Oxidizing power of precipitate in terms of $K_2Mn_2O_8$.	Theoretical for MnO_2.	Apparent per cent of theoretical.	Corrected per cent. for burette error.
c.c	c.c.	c.c.		
40	15.55	16	97.20	97.82
45	17.70	18	98 33	98.92
60	23.37	24	97.40	98.04

Showing an error of from one to two per cent.

The following determinations were made about last February, but no particular record of the details of the manipulation were preserved:

25	9 93	10	99.30	98.34
50	19.73	20	98.65	99.07

It is evident from inspection of these results, that the first set approach very nearly to the theoretical figure for MnO_2, the average of the four happening to be 99.99 per cent. This close agreement with theory must, however, be considered as largely accidental, as the variation in the separate determinations is quite large. In a process of this kind we must consider that the experimental errors are relatively large; indeed, larger than in the actual application of the method to analysis. These experimental errors, doubtless, balance each other to a large extent by averaging several results, as in the present instance; but we can hardly expect to get such close average results every time.

The burette was calibrated for each analysis by weighing the amount of water delivered corresponding to the various volumes used, and making proportional corrections.

Now, if the composition of the precipitate had been $10MnO_2+MnO$, as claimed by Mr. Stone, the oxidizing power found should have averaged 90.91 per cent. of the theoretical figure for MnO_2, instead of that which we have actually found; so that the difference is far too great to admit of any doubt as to the true composition of the precipitate. We may safely conclude, then, that the precipitate obtained in this process, when due regard is paid to the precautions which we have indicated, is MnO_2, and not an indefinite or definite mixture of oxides, that the process is reasonably accurate, and that any estimation based upon the theory that the precipitate is not MnO_2, is of no value, because it is founded on false premises, and therefore can never be true save by accident.

AN HYPOTHESIS OF THE STRUCTURE OF THE COPPER BELT OF THE SOUTH MOUNTAIN.

BY DR. PERSIFOR FRAZER, PHILADELPHIA.

THE rocks which cover the east flank of the South Mountain are chloritic schists typical in character. A specimen of this rock from near the Bechtel shaft, Hamilton Ban Township, Adams County, Pa., was selected and analyzed in my laboratory by Mr. C. Hanford Henderson, with the following results:

Ignition,	2.740	CaO,	7.040
SiO_2,	41.280	MgO,	7.486
Al_2O_3,	18.480	K_2O,	2.208
Fe_2O_3,	9.440	Na_2O,	3.523
FeO,	8.200		100.397

As one penetrates the range by moving westward, these schists are replaced either by epidotic quartz or by orthofelsite. In the former case, a belt of copper-bearing rock is traversed, but not in the latter case. Inasmuch as this junction of the chloritic schists on the southeast and orthofelsite on the northwest, separated by the epidotic quartz, is several times repeated, we find two or three copper belts arranged in general parallelism to the axis of the chain, because the copper horizon is generally at this junction. Thus, in going west from Fairfield, after entering the low spurs on the South Mountain, one is fairly within the chlorite measures.

At the "Virginia Mills" a chlorite schist comes in with a dip of S. 15° E.–74°. Half a mile up Middle Creek, large numbers of fragments of chlorite schist, decomposed epidotic matter, and quartz are encountered. The former rock, where in place, dips E. 40° S.–57°. About 4000 feet west of the intersection of this road with the so-called Tape-Worm Railroad, near the house of one Singly, large masses of chloritic schist are found loose on the road. A hundred yards farther west, near a triangle in the road, the latter is less in quantity and much epidotic quartz appears, after which a very large display of orthofelsite succeeds on the left bank of Middle Creek. All these last-mentioned rocks, however, are in fragments. Crossing the stream again a few hundred yards farther on, the chlorite fragments at first preponderate, and then large numbers of both rocks

seem to be indiscriminately mixed. It is evident, however, that in this eastern part of the South Mountain, the succession (towards the west) of the rocks traversed is chlorite, epidotic quartz, and orthofelsite. If the analogies to other repetitions of this kind, shortly to be alluded to, do not prove fallacious, and if the hypothesis of the occurrence of copper be well founded, we have passed here one of the cupriferous belts.

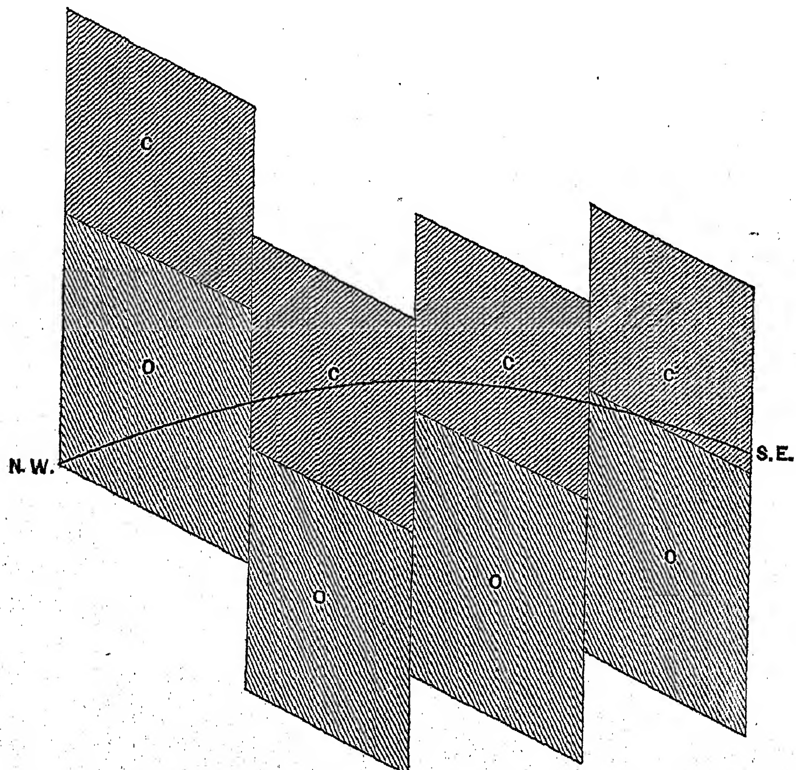
On the wagon road, a couple of hundred yards to the eastward of the sharp nose of Musselman's hill, an orthofelsite gave S. 45° E. –68°, while at the nose itself, the same rock showed S.E. –32°. From this point straight up a line dividing the hill into two halves, one leaves the orthofelsite almost immediately (although if the contact were normal, this part of the hill should lie wholly in orthofelsite), and the fragments become first epidotic quartz, and just before reaching the shaft-house, which is about 120 feet below the summit of the hill, almost exclusively chlorite schists. Following the road westwardly across the notch made here in the mountain, and turning south by west along the bend of the ridge, one is soon again in orthofelsite. Farther to the southwest the transition to chlorite schist appears to occur without the intermediate band of epidotic quartz, and apparently also without the accompanying copper which is usual in the latter rock.

There are many more instances of this state of things, *i. e.*, the succession of chlorite and orthofelsite with and without an intermediate belt of epidotic quartz, and the occurrence in the latter of native copper; but it is believed by the writer that, when the detailed geology of this region comes to be worked out, it will be found that this is repeated very often, and is, in fact, the key to the structure. It remains to offer an hypothesis to explain it.

It is well known that extensive faults traverse the old Palæozoic Valley to the northwest of the South Mountain, and a number of geologists see, in the puzzling monoclinal northwest dip of the Mesozoic measures to the southeast, a repetition of the same class of phenomena (though the writer has doubts as to this).

But the great width of the South Mountain chain, along the Chambersburg turnpike, the abrupt protrusion to the east of the eastern part of the chain south of the Chambersburg-Gettysburg turnpike; and of the western part of the chain to the west, north of this line; and the contacts of Palæozoic and Eozoic rocks of very different horizons in the middle portions of the chain, all point to the existence of extensive longitudinal and transverse faults in these meas-

ures. The chlorite schists overlie here, as in Canada and Wales, the petrosilexes, eurites, or orthofelsites, both dipping ± S.E., but at different angles. When this transition is made directly, therefore, it would seem that the former were laid down immediately on the latter after an interval of time, which had covered several regional movements of the crust of the earth. Subsequently to the formation of both series, fissures had been produced, accompanied with either up- or down-throws, of which the result was to bring together unconformably the orthofelsites and the chlorites. It is attempted to express graphically this hypothesis in the accompanying sketch.



The black line in the above sketch represents a vertical transverse section of the South Mountain; C represents the chlorite areas, and O the orthofelsite.

These fissures were subsequently filled with the materials now apparent as the epidotic quartz, carrying the native copper. That these materials were originally in the form in which we now observe them is not necessary to this hypothesis, nor is it probable. There are few more certain indices of metamorphism than the occurrence

in quantities of epidote; and the condition of the copper in small grains, disseminated widely through this whole mass, is not what one would expect in such a mode of deposition.

It is worth while to compare this phenomenon, however, with the cupriferous horizon in the Michigan peninsula, no matter how diverse their ages may be. In both cases the appearance of the copper has been intimately connected with the production of fissures, and the filling of these fissures from below, either with the "water-molten," the fused, or the dissolved ingredients of the deeply buried strata. It may indeed be asked how far we are able to distinguish the era of the genesis of the copper in the two districts, even accepting the great difference in age between the Arvonian-Huronian measures of the South Mountain and the Keweenian measures of the Michigan peninsula.

Note.—A convenient method of illustrating faults was resorted to to furnish a basis for the above sketch. The upper and lower inclined lines, and the divisions between the chlorites and orthofelsites, having been drawn as three inclined and parallel lines, the paper was cut through the vertical lines representing the faults. These strips were run through horizontal slits on another sheet of paper just broad enough to receive them. To avoid making these slits run into each other, each pair was made higher or lower on the backing sheet than the pair alongside of it. By drawing these slips up or down through the backing paper, the various kinds of unconformable contact across the faults can be repeated.

THE COPPER DEPOSITS OF THE SOUTH MOUNTAIN.

BY C. HANFORD HENDERSON, PHILADELPHIA.

The belt of copper-bearing rocks of the South Mountain has attracted attention principally in the townships of Hamilton Ban and Liberty in Adams County, Pennsylvania, and in the southeastern portion of Franklin County. As the developments, thus far, have been almost exclusively limited to that area, the examination here described extended only within those boundaries.

The region, being one of considerable interest geologically, has been the subject of careful study and description, both on the part

of the State geologists and also of visiting scientists. What has been so well said by them it is not my purpose to repeat, except in a general way; but their examinations having been, for the most part, made some years ago, a brief account of the present state of the exploitations may not be uninteresting to those acquainted with the locality.

The horizon of these cupriferous rocks, as is well known, has been determined to be that of the Huronian, and the disputed question of their identity with the copper-bearing horizon of the Lake Superior region has been decided negatively. Since the Huronian measures are separated from the Keweenian of Michigan by many thousand feet of accumulated sediments, the study of the Pennsylvania field must be conducted independently, and all reasoning in regard to the continuity and richness of the deposits of copper must rest entirely upon observations made in the field itself, rather than from any analogy to the Lake Superior districts.

The accompanying map, reduced from one made by Mr. Lehman for the State Survey, covers the area examined, and a reference to it will show the position of some of the more important properties with respect to each other, and the general direction and location of the cupriferous zone.

A ride of fifteen miles from Waynesboro, over Antietam Creek, through Caledonia Springs, and across Green Ridge, brings one to the farm of James Bigham. This formed the northern limit of the present examination. The adjoining farm of Baker, still further to the north, is also included in the copper belt, and fair specimens of native copper and carbonates are reported to come from that locality.

The property of Mr. Bigham comprises two hundred and thirty-six acres, lying on the eastern slope of Green Ridge. The nearest railroad communication is at Gettysburg, some twelve miles distant. The new railroad, now building from Carlisle to Gettysburg, will pass within two miles of the farm.

At present, no work of any kind has been done upon the property, and the only materials available for examination are found in the occasional outcroppings of the country rock, and the fragments of rock and copper-bearing epidosyte strewn over the surface.

Crossing the property from west to east, the geological sequence, beginning near the middle of the chain, is as follows: First, is found the orthofelsite, a rock known locally as porphyry, and consisting of a compact pinkish matrix, with imbedded crystals of decomposing feldspar. In places its porphyritic character is hardly noticeable,

and, instead of being as before massive and compact, it becomes decidedly laminated and shaly in its structure, and passes into the orthofelsite shale. Analysis "A" gives the composition of this rock.

Following this, is chlorite schist, a tough, dark-green schistose rock, which is prominently developed in the woods, west of Bigham's house. Here its strike is N. 15° E., its dip being 54° to the southeast.

Next comes the copper-bearing rock, which is composed of epidosyte (Dana's name for the mixture of epidote and quartz), impregnated with native copper, and in places showing the green and blue colors of the copper carbonates. On the Bigham farm this formation was not seen in place, but was indicated by fragments scattered over the hillside. Succeeding this a belt of orthofelsite again manifests itself by its numerous fragments.

The copper belt extends through the Bigham farm for a distance of from seven-eighths to one mile, and then passes southwardly into the Musselman Hill tract, the property of the Harrisburg Copper Company. The copper-bearing zone is found at the contact of the chlorite schist and the orthofelsite. In places the epidosyte lies directly between the two formations, distinctly separating the chlorite from the orthofelsite, while in other localities again it is found inclosed on both sides by the chlorite, though lying but a short distance from the contact with the orthofelsite.

On the summit of Musselman Hill a vertical shaft has been sunk to a depth of fifty-three feet. It is reported that, on starting the shaft, the ore-body dipped to the west, but, as the work progressed, it soon regained its characteristic dip—a little south of east. In that case, the exploitation would be partially in productive, and partially in unproductive ground.

The ore, taken from a depth of fifty feet, is a compact, unaltered epidosyte, with the copper present entirely in the metallic state. Analysis "B" (5.83 per cent. of metallic copper) is of a mass of this rock selected by the manager as a representative piece of the ores found at that depth. The bottom of the shaft shows two apparently well-defined walls of chlorite separated by about eight feet of epidotic rock. The dip here is the same as that shown by the outcropping chlorite lower down on the hillside, that is, steeply inclined to the southeast.

Nearer the surface, the ore contains the copper partially changed to cuprite and to the blue and green carbonates, azurite and malachite. Trenches, dug in the vicinity of the shaft, have in most cases

disclosed an ore of this nature. Analysis "C" is of a piece of ore selected from the dump-heap on Musselman Hill, not as a representative of the whole pile, but simply as a sample of the carbonate stained ores, which were mixed with the barren chlorite; the result (16.44 per cent. of metallic copper) was unexpectedly high, and much above anything that could be expected in quantities. Masses of native copper, weighing from three to four pounds, are said to have been found on the property; these, however, are exceptional.

Several different ore-heaps have been formed on the ground around the shaft-house; the largest of these, containing about twelve tons, was carefully sampled by taking fragments at regular intervals around the periphery of the pile, and also at similar intervals from several cross sections. The resulting sample was, by suitable reduction, got into a compass convenient for transportation, and in the laboratory the greatest care was taken that the few grams employed for analysis should represent as exactly as possible the mean value of the larger sample. Analysis "D" (1.82 per cent. of metallic copper) is the result thus obtained. While this represents the value of the average ore obtained under the present management, it is quite possible that the percentage of copper in the mine output could be increased considerably by more judicious exploitation. This possible increase, however, is demonstrable only by experiment, and for the present, therefore, the question remains problematical.

To the south of the shaft, the hill ends abruptly, and its steep sides show a considerable exposure of chlorite and weathered epidosyte. The dip of the chlorite is almost identical with that on the Bigham farm, being 52°, a little S. of E. This steep outcrop would have been an admirable site for the location of a tunnel; its advantages over the present shaft are very evident. As a means of exploitation, also, the tunnel would be of more value, since it would penetrate the deposit at a much greater depth and consequently prove it more effectually.

At the time of my visit, the force working on the shaft consisted of but three men and a boy. The entrance and exit to the mine is gained in the most primitive manner. The hoisting apparatus is correspondingly crude; a hand windlass serves to raise and lower the one bucket which carries both the ore mined and the water accumulating at the bottom of the shaft. The whole exploitation so far has been conducted with little system or regularity, and the results do not fairly represent the capabilities of the region.

Immediately to the south of this property lies the Keiholtz farm.

A steep hill rises to a height of four hundred feet above the creek, and should any systematic exploitation be projected, this steep incline would probably form the best possible site for such operations.

Passing southward over this farm to the Rummel and Culp properties, some little excavation is found on the latter, and Analysis "E" (5.93 per cent. of metallic copper) is of ore taken from that dump.

The next prominent locality is the Bechtel shaft on the property of the South Mountain Copper Company. This shaft was then under lock and key, as well as full of water, so that no direct observations could be made. It was reported, however, to have gone to a depth of one hundred and twenty feet between two well-defined walls of chlorite, inclosing eight feet of cupriferous rock, the ore being still found at the bottom of the shaft. The dump contained a quanity of carbonate-stained ores. The exposure of the chlorite west of the shaft showed a dip of 34°.

A second shaft on the same property, but located to the northeast of No. 1, had evidently not been worked for some time. It had gone to a considerable depth, but in the absence of ladders was not accessible for exploration. The dump heap, however, bore strong evidence to the fact that the shaft was located at the contact of the two formations, as on one side the pile was exclusively composed of the pinkish orthofelsite, and on the other nothing was visible but the green color of the chlorite. Pieces of quartz scattered over the dump carried small masses of specular ore, and indeed throughout the whole region the hematite appears as a constant accompaniment of the copper.

Adjoining the South Mountain Company's property, and following the copper belt southward, lie successively the Russell, Woodring, Old Copper property, Balsley, Shingledecker, Weagley, Gilbert, Hess, Gladhill, Pittinger, White, and Headlight tracts. Excepting the latter, but little or no developments have been made on any of them, though they all cover formations similar to those underlying the copper properties to the north.

At the Headlight property, lying on the border of Franklin County, a tunnel has been driven directly under the turnpike. It has penetrated the hill for a distance of about one hundred and sixty feet, and at the time of my visit was said to be progressing at the rate of a foot a day when the rock was not too tough. At that time it was calculated that twenty feet more would bring

the working into the main copper ore-body. At the time of a second visit admittance to the tunnel was not permitted; specimens, however, reported by the men to have come from the present heading, showed a very quartzitic ore impregnated with native copper. The tunnel has been driven through chlorite, and passes at an oblique angle through a secondary copper zone.

This locality formed the southern limit of the present examination; the same belt, however, can be traced into Maryland, and ores of a similar character are reported to come from the farm of Wagaman, some four miles south of the Headlight property. The examination covered a distance of about eight miles, while the reported occurrence of the zone at Baker's on the north and at Wagaman's on the south would extend the known continuance of the belt to some thirteen miles, with no evidence of termination at either limit.

Such then is the state of the exploitations in the South Mountain Copper District. For upwards of seventy years, the region has been, from time to time, the scene of mining operations, but so far none of the enterprises seem to have been crowned with success.

Since the deposit is a continuous one, and many thousand tons of the epidotic rock could be easily mined above water level, the essential difficulty seems to lie in the fact that the ore is too lean. Whether the percentage of copper could be so far increased by judicious mining as to overcome this difficulty it is impossible to say; competent judges, however, think it improbable.

Table of Analyses.

A.

Ignition,	.40
Silica,	73.62
Alumina,	12.22
Ferric oxide,	2.08
Ferrous oxide,	4.03
Lime,	.34
Magnesia,	.26
Potassa,	2.57
Soda,	3.57
	99.09

B.	Met. copper (determined as CuO),	5.83	per cent.
C.	" " " " "	16.44	" "
D.	" " (determined as metal)=1.80 / (determined as CuO)=1.84	1.82	" "
E.	" " " " "	5.93	" "

CAST IRON OF UNUSUAL STRENGTH.

BY EDWARD GRIDLEY, WASSAIC, N. Y.

MEMBERS of the Institute who were present at the Amenia, N. Y., meeting, in October, 1877, will remember their visit to the hematite mines, just west of the village of Amenia, and some of them may perhaps recall the deposit of carbonate ore south of the opening made for the hematite. The smelting of this carbonate during the last few months, has produced an iron that seems worthy of being brought to your notice. A little more than a year ago, at the Wassaic Furnace, Dutchess County, N. Y., we made a few hundred tons of iron from a mixture of two-thirds raw carbonate and one-third Chateaugay ore, hoping that it would be suitable for steel purposes, but as the iron showed phosphorus 0.189 per cent., it was not offered. This iron looked well and seemed quite strong, and gave good results in malleable castings; but no special tests of strength were made.

About February 1st, of this year, we began using two-thirds roasted carbonate, and one-third Chateaugay, and noticing that the iron was stronger than usual, we had two samples tested, which showed tensile strength of 32,014 and 34,176 pounds per square inch. After our stock of Chateaugay ore was exhausted, we put on one-third raw carbonate with the two-thirds of roasted carbonate, and the first test made of the iron, showed 40,008 pounds per square inch.

The three tests given above were made by Mr. A. J. Copp and Mr. E. B. Manning, of the Phœnix Furnace, Millerton, N. Y., on a machine of Riehlé Bros., Philadelphia. Since these tests were made, they have broken samples made with all carbonate ore as follows: 39,669, 40,816, 41,882, 42,281, 39,902, and 40,130 pounds per square inch.

A test taken from the same bed of iron as the last-mentioned (40,130), was broken by Mr. A. Blass, at Irondale Furnace, showing 40,151 pounds per square inch. A sample broken on the Riehlé Bros. machine, at Stevens Institute, under direction of Professor R. H. Thurston, showed 40,000 pounds per square inch. Another sample was broken by Professor Thurston on his torsion machine, and gave torsion 7°, and tensile strength of 44,500 pounds. And

still another sample, broken by Davenport, Fairbairn & Co., Erie, Pa., on their Thurston torsion machine, gave torsion 9°, and tensile strength 47,500 pounds per square inch.

These tests were all made from iron cast in the pig-bed, direct from the furnace. Some were made from the full pig turned down, but most of them from samples obtained by making a hole in the sand at the end of the pig, from 10 to 20 inches long, and about 1¼ inches in diameter. No tests have yet been made from the re-melted iron.*

I add an analysis of the roasted ore, made by Messrs. Booth, Garrett & Blair, February, 1883, and an analysis of the iron, made by Dr. T. M. Drown, May, 1883.

Analysis of Roasted Carbonate.

Silica,	8.240
Peroxide of iron,	77.202
Alumina,	2.768
Red oxide of manganese,	3.005
Lime,	1.650
Magnesia,	1.167
Phosphoric acid,	.275
Sulphur,	.224
Loss, by ignition,	5.684

Metallic iron,	54.042
Metallic manganese,	2.165
Phosphorus,	.120

Analysis of Pig Iron.

Graphite,	2.310	Total, 3.090.
Combined carbon,	.780	
Silicon,	1.307	
Sulphur,	.086	
Phosphorus,	.294	
Manganese,	1.512	
Iron,	93.700	
	99.989	

* Since the above was written I have received report of two samples broken by Messrs. Fairbanks, on their large machine, May 31st, 1883, showing 39,068 and 41,629 pounds.

• The average of the thirteen tests is 41,349 pounds.

THE LANGDON GAS PRODUCER.

BY N. M. LANGDON, CHESTER, N. J.

On account of its greater economy and cleanliness, and the extent to which inferior fuels can be utilized for its generation, there has been of late a rapidly increasing tendency to substitute gaseous for solid fuel for metallurgical and other industrial purposes, which has led to various improvements both in the process and apparatus for its manufacture, notably among which may be mentioned the Tessié Gas Producer* described by Mr. A. L. Holley.

A considerable experience by the author with producers of various kinds using anthracite fuel, in connection with the Taylor ore-roasting furnace at Chester, N. J., with more or less unsatisfactory results, finally led to the erection of the experimental producer described below, which combines in its construction, simplicity, durability, and accessibility for cleaning and removing the ash and manipulating the fuel. It is adapted to the use of various kinds of fuel, and is capable of generating a steady and uniform supply of gas at a minimum cost. It has been in constant use day and night for about five months, and has given very satisfactory results.

The producer, as shown in the accompanying sketch, consists of a cylindrical furnace, preferably inclosed in an iron jacket or casing, having a bosh or inverted cone-shaped base as in a blast furnace. It is provided with a bell and hopper, the bell being hung to a forked lever, and having guide flanges to prevent it from swinging, and an opening at its apex through which to insert a bar for manipulating the fuel, which when not in use is closed with a plug or stopper. Cleaning is effected through two small doors placed opposite each other at the hearth level, which in order to facilitate the operation is elevated above the floor. The doors are removable, and when closed are by their own weight and by means of bevelled lugs held tightly against their frames, forming a practically tight joint. A blast of commingled steam and air is injected into the fuel through a series of tuyeres underneath the bosh communicating with steam jet injectors. A small flue also connects the door

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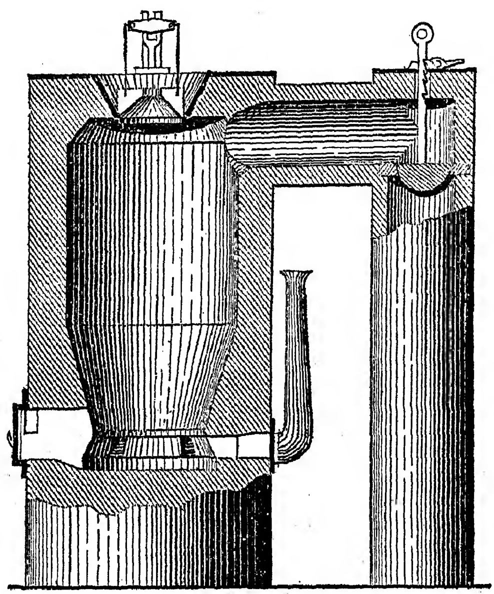
* *Transactions*, vol. viii., p. 27.

passages with the injectors, and a portion of the blast entering in this way prevents the doors from becoming overheated and warped.

The air in combustion with the fuel (anthracite) forms carbonic oxide and nitrogen. The steam is decomposed and forms carbonic oxide and hydrogen or hydrocarbon gases, adding to the value of the combustible gas not only by the amount of hydrogen gases present,



but also by the amount of carbonic oxide which is formed free from the diluting nitrogen. The steam also prevents the formation of hard clinkers, and the ash from sintering to the walls of the producer.

No analysis of the gas has yet been made, but comparing it, in result, with gas previously used, containing 25 to 28 per cent. carbonic oxide, for roasting and desulphurizing ores, a saving of 15 per cent. in quantity and 15 to 20 per cent. in quality of fuel is effected.

The gas passes off through an exit flue at one side near the top, which is provided with a damper. In cleaning, the fuel in the upper part of the producer is held up by the sloping walls of the bosh while the ash below is removed. After cleaning, the fuel is settled and evenly levelled or distributed with a bar introduced through the opening in the bell.

Both anthracite and bituminous coal and coke dust have been used, our usual practice being $\frac{2}{3}$ to $\frac{3}{4}$ pea coal and $\frac{1}{3}$ to $\frac{1}{4}$ coke dust. It is obvious that charcoal braize, peat, etc., can be used advantageously.

*THE SHELF DRY-KILN.**

BY C. A. STETEFELDT, NEW YORK CITY.

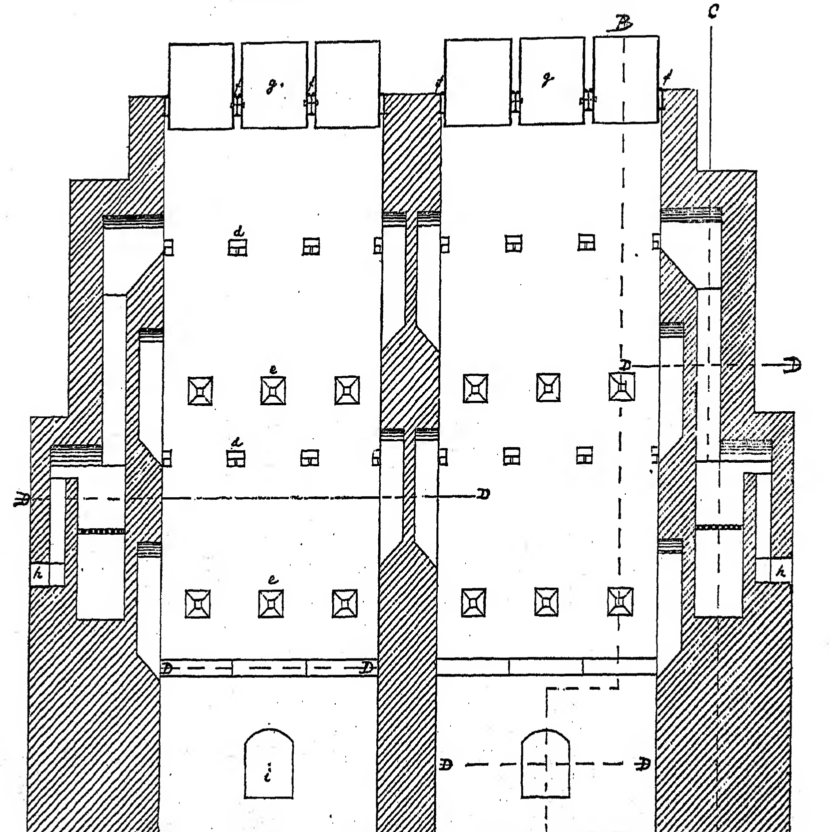
IN the dry-crushing of ores, either by stamps, rolls, or other machinery, it is essential that the material should be free from moisture. Hence a contrivance which effects this with economy, and is of durable and compact construction, is a great desideratum. It is claimed for the below-described shelf dry-kiln, that it possesses these qualifications in a high degree.

The construction of the shelf dry-kiln is based on the Hasenclever principle. That is to say, a number of inclined shelves are arranged zig-zag above each other in a vertical shaft, having openings or slits where they meet, on which the ore rests in a stratum, the thickness of which is governed by the width of the slits and the inclination of the shelves. If a portion of the charge is removed at the end of the bottom shelf, a sliding motion of the ore takes place on all shelves above, and the top shelf is replenished from a hopper set over it. It will be seen that the shaft is divided by the shelves into a number of triangular prismatic spaces. Through these the hot gases from a fireplace are made to circulate, each space communicating with the next one by a flue arranged in the sidewall of the shaft. These flues being located on alternate sides of the shaft, a continuous passage is formed through the whole structure.

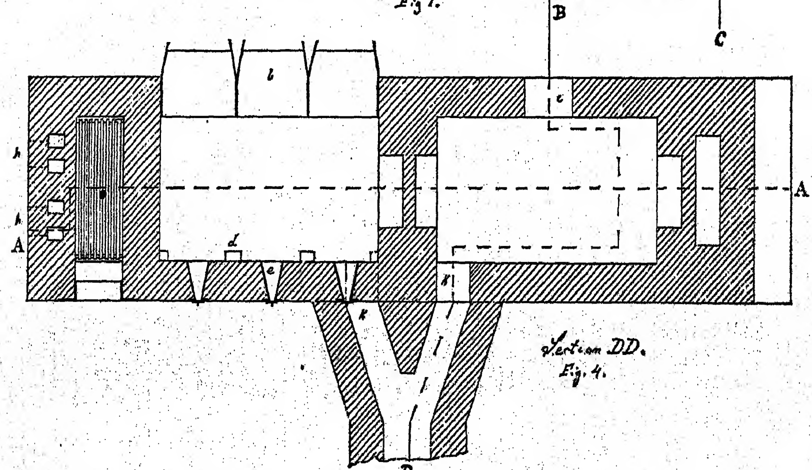
After thus stating the principle of the construction, its details will be easily understood by reference to the drawings, Fig. 1 to Fig. 5. The drawings, Fig. 1 to Fig. 4, represent two kilns united into one structure. The cast iron shelves(*a*) are 2 feet 4 inches wide and 5 feet long, with sides and a back 4 inches high, and are cast a full half-inch thick. How they rest on the brackets(*d*), and interlock each other, is shown in Fig. 5. Three such shelves, with an inclination of 38°, are placed in one row in a brick shaft 7 feet ½ inch wide and 4 feet deep. The ore hoppers(*g*) rest on the iron beams(*f*). At the end of the bottom shelves are the discharge-doors(*b*), with shoots projecting beyond the front wall. A swinging apron(*c*) keeps the ore in place. By dropping it a car below the shoot is filled with dry ore. A number of extra-large pieces of ore may cause a stoppage in the slits; for such an emergency the openings(*e*) are provided, through

* Covered by U. S. patent, granted to C. A. Stetefeldt, March 1st, 1881.

which a poker can be inserted. The fireplace, with air-channels(h),

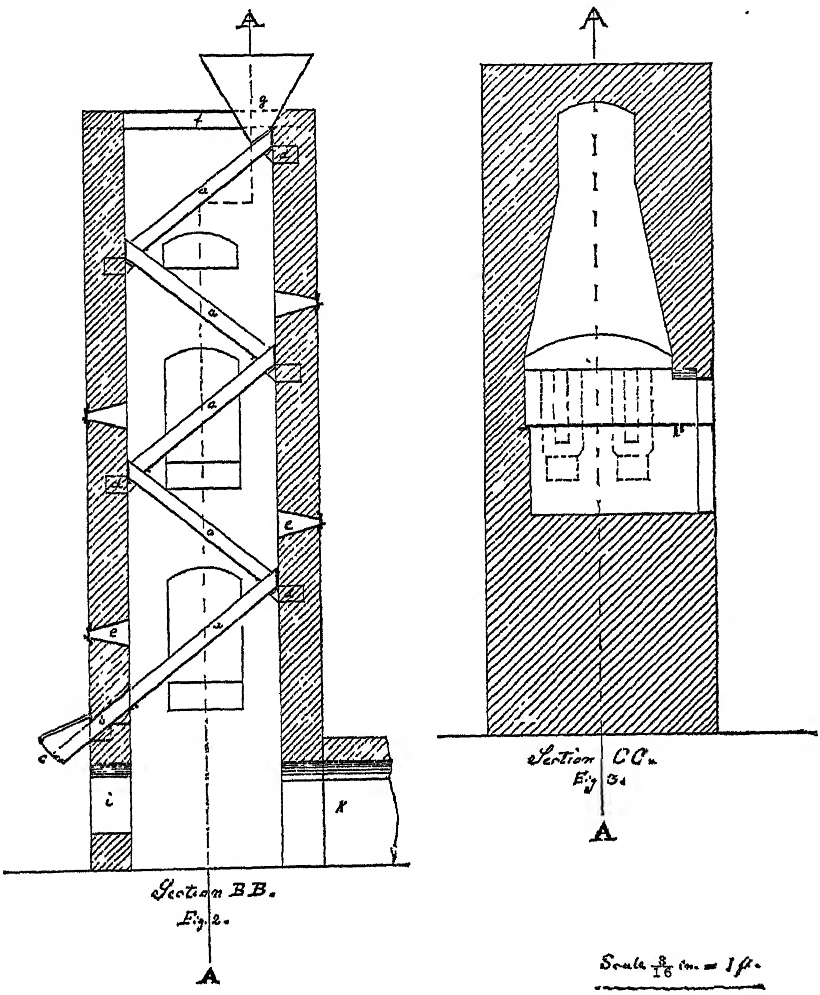


Section AA. Note. The shelves (a) are left out in this section.
Fig. 1.



Section DD.
Fig. 4.

is located near the base of the kiln, but its hot gases enter below the top row of shelves, and move downward, finally escaping through the flue(k), which is connected with a chimney. Such an arrangement is made for very good reasons. If the fire entered below the bottom row of shelves, which are filled with dry and hot ore, a careless laborer might overheat and warp them by too heavy firing. As



it is, the greatest heat strikes those shelves which are filled with cold and moist ore, and overheating can hardly occur. With a downward draught the temperature of the kiln is very uniform, and the evaporated moisture cannot condense again by coming in contact with cold and wet ore. The opening(i) in the front wall is closed either by

a brick wall or a sheet-iron door. The height of the kiln from the discharge floor to the top of the hoppers(g) is 21 feet, more or less, depending somewhat on the height of the car to be used for transporting the dry ore to the crushing machinery. The brickwork is heavily anchored with beams, rails, bolts, and buck-straps, which are not shown in the drawings.

In constructing the kiln none of the shelves are put in position until the shaft is finished to the level of the beams(f), and the brickwork is fully anchored. In order to avoid difficulties in placing the shelves, it is best first to fit them, set after set, into an exact wooden model of the shaft (2 feet 4 inches wide), which is put up on the fireman's floor, not in a vertical, but in a horizontal position.

Since a good draught is essential for drying the ore quickly, the chimney should rise not less than 30 feet above the top of the kiln. For one double kiln a draught area of 3 square feet is required.

In case the kiln is used for drying salt some remarks about its operation may not be out of place. The wet salt, on the top row of

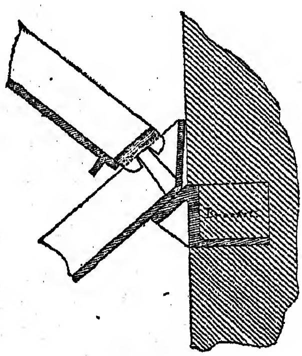


Fig. 5.

shelves, first bakes into a solid cake. By increasing the fire decrepitation of the salt-crystals commences, and the whole mass is shaken loose, with the exception of a crust on the top. This is broken up by means of a light poker with chisel end. If the fire is kept right no rebaking of the salt takes place on the second row of shelves, but violent decrepitation continues here and lower down. The constant impact of the decrepitating salt crystals has, in the long run, a destructive effect on the walls of the kiln if they are built of ordinary soft brick. Hence it is necessary to line the salt kiln with very hard-burnt common brick, or with firebrick. The drying of the salt is very perfect. Two double kilns for ore and one single kiln for salt have been in operation at the Lexington Mill, Butte City.

Montana Territory, since September 1st, 1882. Mr. A. Wartenweiler, a member of the Institute, gives the following statistics as to the capacity, and consumption of fuel and labor, of this plant. The two double kilns put through 54 tons of ore, with about 4 per cent. of moisture, and consume 2 cords of wood in twenty-four hours. In calculating the consumption of wood for several months it is found that 0.039 cord of wood is used for drying 1 ton of ore. One single kiln puts through 8 tons of salt (dry weight), with about 6 per cent. of moisture, and consumes 1 cord of wood in twenty-four hours. In calculating the consumption of wood as above, it is found that 0.11 cord of wood is used for drying 1 ton of salt. The capacity of the salt kiln is somewhat overtaxed, and a heavy fire has to be kept. In consequence, the upper shelves, next to the fire, warp after some time.

One man in each shift attends to the fireplaces and the salt kiln, and one man in each shift discharges the dry ore and salt, and transports it to the self-feeders of the batteries. All shifts in the mill are eight-hour shifts.

The weight of the iron plant for one double kiln, consisting of castings, wrought-iron work, beams, rails, buck-straps, and bolts, is about 25,000 pounds. The quantity of brick required is 30,000. It may be stated that everything is constructed with a view to durability.

Compared with the revolving or cylindrical dry-kiln, the following advantages are claimed for the shelf dry-kiln:

1st. Greater compactness of construction, and greater durability.

2d. Greater economy in fuel, since very little heat is lost by radiation, and the heat is better utilized by travelling through a much longer space.

3d. No power is required in its operation.

4th. It produces no dust, hence there is no necessity of erecting dust-chambers, and no loss in precious metals from this source.

GOLD MINING IN SOUTH CAROLINA.

BY E. GYBBON SPILSBURY, HAILE MINE, S. C.

From time to time, for the last quarter of a century, considerable attention has been called to the gold deposits of North Carolina and Georgia, and much capital has been expended in their development; but the existence of large areas of gold-bearing rocks in the State

of South Carolina is known only to comparatively few. The production of the South Carolina mines, being usually disposed of at the United States branch mint in Charlotte, has been generally credited to the North Carolina or Georgia mines. The mines of Lancaster and Chesterfield counties, South Carolina, have for years been as large producers as any in the neighboring States, and many of them have mint records of yields ranging in the millions. Before the war, most of these deposits were worked in a more or less desultory manner, down to about the water-level, and then stopped; and it is only within the last few years that operations have recommenced in any of them. At the present time, even, there are only four mines of any magnitude operated in the State. These are, the Haile Gold Mine and the Funderburk Mine, in Lancaster County; the Brewer Mine, in Chesterfield County; and the West Mine, in Union County.

I am aware that the general impression is not favorable to gold mining in the South, owing, doubtless, to the almost general failure of the many companies which have started work in this section. Still, to those who have studied the geology of the country and are acquainted with the auriferous deposits, it will not sound like exaggeration when I say that there is more money to be made to-day in gold mining in the Carolinas and Georgia, with a moderate outlay of capital, than in any equal area in California. The question very naturally arises then: Why, if this is the case, are there not more successes and fewer failures? The answer to this seems to me very plain. Under the old slave *régime*, gold-washing and mining were generally carried on in a very desultory manner and on a small scale, each landowner just working on his own farm, using his overseer to manage his negroes in the mines as well as on the farm. Thus, both the overseers and negroes gradually obtained more or less knowledge of mining and milling such as they had seen on their neighbors' plantations, and which was of the most rudimentary character. After the war, when the attention of outside capital became attracted to these mines, these people became naturally the miners and foremen of the district. Their shiftless and irregular manner of working, which yielded profit enough to satisfy small individual owners, proved insufficient to grapple with the real difficulties of regular mining and milling, and hence arose the impression that the Southern ores were hard to mine, and harder yet to reduce.

This view was strengthened by the patent-process men, who came in swarms, each to be the deliverer from some terrible difficulty which

the extraction of the gold from these ores presented. The process, when completed, would not always work right, and hence the inevitable collapse and general engendering of distrust in the value of the properties.

As a fact, however, the average ores of the South present fewer difficulties of treatment than do those of the West, to any one who is at all acquainted with the requirements of the case. For instance, what would be thought in Colorado of a mining engineer who would put up a stamp-mill and amalgamation-works to treat cupriferous pyrites carrying gold? Yet I know of several cases where this has been tried in the South.

Another cause of failure has been the general exaggeration of the values of the ores. As a rule, the surface ores in this section are very rich, owing to a gradual concentration of the gold as the matrix is decomposed by atmospheric influences: whereas the general deposits are of comparatively low-grade ores when once water-level has been attained. Of course, there are exceptions; but this I find to be the general rule.

As the Haile mine is essentially a low-grade mine, and is still one of the largest bullion-producers, if not the largest, of the South, a short description of the mine and system of treatment of the ores may not be out of place.

The mine property, consisting of a tract of some 1900 acres, is situated in the southeastern corner of Lancaster County, South Carolina, about one and a half miles from the Kershaw line. The formation of the country-rock is talcose slate, having a general trend of north 18 degrees east. These talcose schists are tilted up on end, being in places nearly vertical, and nowhere having a dip of over 20 degrees to the northwest. They are throughout very highly impregnated with fine crystals of iron and arsenical sulphides. The beds of auriferous rock seem to follow in general direction the trend of the country-rock. There are at least two distinct mineral belts running in a parallel direction through the property. A series of trap dikes cut through the slates almost at right angles; and although there appears to be no lateral dislocation caused by these dikes, still they probably bear some intimate relation to the mineralizing of the belts they cross. The main or Haile deposit has been traced over a distance of three miles, and has been worked on for many years, down to a depth of about 60 feet. Its general width may be taken at 65 feet. The average value down to the bottom of the present workings, 75 feet from the surface, is about $11 per ton,

although bunches of high-grade ores are sometimes found. The ore is undoubtedly an altered slate, and to an inexperienced eye differs very little from the surrounding country-rock. In reality, however, in composition it is nearer a quartzite than a talcose slate, the magnesia being replaced by silica, and contains in places, near the centre of the beds, over 80 per cent. of silica. From this, it gradually diminishes in hardness toward the walls, the foliations become thinner and more marked, interspersed with thin seams of pure quartz, until gradually soft talcose slate is reached. There is no actual line of demarcation visible, except in a very few places near the surface. The amount of gold also diminishes very gradually, and indeed none of the surrounding slates, within a distance of 50 feet on each side of the deposit, is without more or less show of gold. From the size of the deposit, mining is of course very cheap, and the introduction of power-drills has brought the cost of extraction down to 80 cents per ton.

Across the valley to the north of this Haile deposit, is another parallel one of almost equal magnitude, known as the Blauvelt vein, the characteristics of which are very similar. These deposits have been worked from time to time in an unmethodical way for the last fifty years, showing, according to the mint returns, a yield of over one and a quarter million dollars. During the fall of 1879, the property was bought by the present company, and the work has been pushed steadily ever since.

The ore is hoisted from the mine up a slope, the same cars taking it down on an elevated tramway to the mill. The mill is an ordinary twenty-stamp, California type, the weight of the stamps being 750 pounds, and the average number of drops 80 per minute. The fall of the stamps is 7 inches average. The screens used are forty-mesh. The amount of ore put through daily is from 35 to 37 tons. The average value of the ore is from $11 to $12 per ton. Of this amount, from $3.50 to $4 is free gold, the remainder being combined and more or less inclosed in the sulphides. The mortars are provided with inside plates, which are taken out and cleaned every day, yielding from $75 to $80 per day. Each battery is also provided with 10 feet of copper plates outside, the average catch of which is about two-thirds more than the inside plates. At the bottom of the plate-tables, I have put in a series of small spitzkasten, with an upward current of water, which I find very effective in catching whatever quicksilver is lost from the plates. All the tailings are then run over concentrators, whereby the sulphurets are saved, the average

tailings, which finally leave the mill, showing less than 30 cents of gold per ton. Our entire cost of milling, including labor, cordwood, wear and tear of machinery, and labor of concentration, is 51 cents per ton, to which should be added 2 pounds of shoes and dies to the ton of ore, say 9 cents, making in all a total cost of 60 cents per ton.

The next process is the roasting of the concentrated sulphides, which, at the Haile Mine, do not contain the faintest trace of copper. To effect this thoroughly, was supposed to be a matter presenting great difficulties, and a special furnace was designed to overcome them. This furnace consists of a large coil 450 feet long, of 5-inch wrought-iron pipe, built in a suitable furnace, and heated to a low red heat. The finely-divided ore is blown through this pipe with a large excess of air into suitable receiving-chambers. Some of the mechanical details of this furnace are not yet perfected; but the roast made by it when working right is most complete, scarcely the faintest trace of sulphur being left in the ore, and it further has the advantage that, through the constant attrition of the particles of ore among themselves in their passage through the pipes, the gold is entirely freed from all scale, and left perfectly bright and ready for amalgamation. Like all mechanical roasters, however, this furnace cannot be relied on for perfectly uniform results; and until this and other mechanical difficulties have been obviated, I have fallen back on the old-fashioned, but always reliable, "fortschaufelungs" furnace. Here in the South, where labor is obtainable at 90 cents per day, where wood costs us less than $1 per cord delivered at the furnace, the advantages to be gained by automatic rabbling, in whatever way attained, are so slight that they are much more than counterbalanced by the perfect control one has all the time over the charge roasted in the reverberatory furnace. The advantages of the latter, in the matter of first cost, are of course undeniable. Our double-hearth furnaces, 40 feet long by 5 feet wide, do not cost us over $800 all complete, and have a capacity of from 6 to 10 tons per day of twenty-four hours. Taking an average of 8 tons per day, the cost of roasting does not exceed $1.10 per ton.

The roasted ores, after cooling, then go to our amalgamation-works, which, from their economy and success, deserve a special notice. It is, I believe, a well-established fact that the old Freiberg barrel-process of amalgamation has always yielded as good, if not better, results than any other process, the great objection to it being the great length of time required for the thorough amalgamation of

the pulp, owing to the difficulty of causing each particle of the gold to come in contact with the metallic mercury, and the consequent excessive flouring of the quicksilver.

In order to obviate this, and cause a more thorough dissemination of the mercury through the charge, Mr. Designolle, a well-known French mining engineer, proposed using a solution of the bichloride instead of metallic mercury, at the same time placing in the barrel enough metallic iron to thoroughly effect the decomposition of the bichloride. This he found so thoroughly successful that he designed and patented a complete combination plant for treating ores by this process. At first, he claimed to be able to treat unroasted sulphides directly; but as a general thing, this claim has proved a failure. On the other hand, with roasted ores it has proved itself even more successful than was at first contemplated. The process is as follows: The roasted ore, in charges of 600 pounds each, is put into a cast-iron cylinder or barrel, in which are also placed about 1000 pounds of cast-iron balls. The cylinder is then partially filled with water, and about half a gallon of the bichloride of mercury solution is added. The barrel is then rapidly revolved for five minutes, at the end of which time another half gallon of the solution is added, and the cylinder again revolved for fifteen minutes. At the end of that time, every particle of gold has been amalgamated, and the barrel is discharged into a large settler, in the concave bottom of which is a bed of metallic mercury. The pulp is kept in suspension in this settler by revolving rakes, which keep the surface of the mercury-bed clean and ready to absorb the particles of amalgam immediately as they settle. The pulp is discharged from this settler in a thin stream over a series of revolving centrifugal copper plates, which catch whatever particles of amalgam may still be held in suspension in it. From the plate machine, the pulp discharges into a second settler similar to the first one, thus finally catching what may have passed through the former settler and the plates. The simplicity of the whole process is remarkable. With our plant, costing in all less than four thousand dollars, including building, we can treat from eighteen to twenty tons per day, with the labor of one man and one boy. The whole cost of treatment at our mill, including chemicals, labor, steam, and wear and tear of machinery, is 38 cents per ton.

Having given a general outline of the manipulation of this process, it may be interesting to look into its chemistry. The composition of the standard solution used is as follows: Mercury bichloride, 1; common salt, 2; muriatic acid, 1. The proportion of the acid

may be varied according as the gold in the charge to be treated is more or less rusty. These chemicals are mixed with any reasonable amount of water, with us the latter being in the ratio of 64 gallons to 8 pounds of bichloride, thus giving us 1 ounce of bichloride to the $\frac{1}{2}$ gallon of mixture. For all ores containing under $\frac{3}{4}$ of an ounce of gold per ton, 1 gallon of the mixture per charge is fully sufficient, after which $\frac{1}{2}$ a gallon extra is added for each $\frac{1}{2}$ ounce of gold additional. The chemical reaction which takes place is $HgCl_2 + 2Fe = 2FeCl + Hg$. This simple reaction is due to the presence of the chloride of sodium in the mixture. Where this is not present, it is probable that the first reaction would be $HgCl_2 + Fe = HgCl + FeCl$, followed by a secondary reaction of $HgCl + Fe = Hg + FeCl$. It was therefore on the former reaction that Mr. Designolle based his invention.

The extreme rapidity, however, with which the amalgamation takes place seems to point to some further action than the above, as we know that the decomposition of mercury bichloride by metallic iron is a comparatively slow process, and that the globules of mercury might revolve for a considerable time in the mass, as in the old Freiberg barrels, without coming in actual contact with the particles of gold. In point of fact, however, it is just this slowness of action which is the chief element of success of the process. Very little if any of the amalgamation, I believe, takes place by the particles of gold coming in contact with globules of free mercury, the secret of the whole success being that when, in the acidulated bath, any particle of the gold comes in contact with the iron, an electrolytic action is at once established, and the deposition of the mercury over the whole surface of the gold is instantaneous. It matters not how minute the portion of the gold exposed to the contact is, the whole of the surface is at once amalgamated. Even gold covered over with rust scales of iron, if exposed on one point only, will become thoroughly amalgamated throughout, the scale breaking loose, leaving the amalgam free. The action is indeed so rapid that, on ore containing $43 per ton showing freely in the pan before treatment, not a trace of unamalgamated gold could be found after the trituration had continued for ten minutes.

A few months since, my attention was called to Professor Eggleston's paper on the defects of the stamp-mill,* and the assertion made by him of the non-amalgability of hammered gold caused me much astonishment. After a careful series of experiments, I have come

to the conclusion that the conditions of the gold under which Professor Egleston made his discovery must differ considerably from the general condition of the gold under the stamps, as in no case could I repeat his experiments with the same results as obtained by him. As the instantaneous amalgamation of gold by contact with iron in the bichloride solution is quite a beautiful sight, I have brought some of our standard solution with me, with some small plates of hammered gold, and as you will see, the instant the iron touches the gold, the mercury spreads like a vail over the entire surface.

Discussion.

Dr. Egleston said that Mr. Spilsbury's experience did not disprove his statements on the difficulty of amalgamating hammered gold. His experiments were made on different pieces and qualities of gold during periods of many months. They were hammered on a clean anvil, and were kept in tubes in contact with mercury for many weeks, and were exhibited before the New York Academy of Sciences several times.

There is no mistaking the fact that hammered gold will not, under ordinary conditions, amalgamate. The conditions of Mr. Spilsbury's experiments, however, are not ordinary conditions and are entirely different from that of the ordinary stamp-mill; for with the chloride of mercury, there is a galvanic action set up which nothing can resist. There can be no doubt that a part of the loss in gold working, especially with heavy stamps, is due to hammering. Dr. Egleston added that he had, as yet, made no experiments with the chloride of mercury on hammered gold, but proposed to do so.

THE BLAST FURNACE OF THE CROZER STEEL AND IRON COMPANY AT ROANOKE, VA.

BY J. P. WITHEROW, PITTSBURGH, PA.

The blast-furnace plant of the Crozer Steel and Iron Company was built under contract by Witherow & Gordon, of Pittsburgh, Pa. The furnace is 70 feet high by 16 feet bosh, tunnel-head 12 feet 8 inches, and hearth 9 feet in diameter. The columns are 20 feet high above furnace level, below which they extend 2 feet. The shell is 23 feet diameter at bottom and 19 feet at top. The plate iron is $\frac{3}{8}$ inch at bottom, and tapers to $\frac{1}{4}$ inch, the top ring being $\frac{5}{16}$ inch.

The furnace is provided with a double bell, which is 8 feet 4½ inches external diameter, and 4 feet 4 inches internal diameter, operated by a 32 x 63-inch air lift, and provided with safety-catch rods. The down-comer, which is surrounded with a spiral iron stairway, is 5 feet 6 inches external diameter and 4 feet 8 inches in the clear, at the bottom of which is placed a dust-catcher. The tuyeres, seven in number, and 7 inches diameter, are placed 5 feet 6 inches above the hearth level, above which there are four circles of bosh-cooling plates, each plate being traversed with a 1¼-inch gas-pipe coil. The furnace is operated with three of the latest Whitwell fire-brick hot-blast stoves, 18 feet in diameter by 70 feet high, and each having over 24,000 square feet of heating surface. (One square foot of the Whitwell surface is equal to from 2 to 3 square feet of any other type of fire-brick stoves for calorific duty.)

The products of combustion from these stoves are taken off by underground flues to an iron chimney, 160 feet high by 8 feet in the clear. This chimney also gives draught to a plant of ten steel boilers, divided into five distinct batteries. Each boiler is 34 feet long, 46 inches in diameter, and contains two 16-inch flues. Eight of these boilers, or four batteries, are expected to furnish an ample supply of steam for the whole furnace plant, leaving a battery of two boilers idle for repairs or cleaning. In the accompanying drawings of this plant it will be observed that an arched flue traverses the foundations, so as to communicate with the chimney for additional batteries of boilers, should a second furnace be added to the plant.

The engine-house is 31 x 40 feet in the clear, and contains two of the newest style of Weimer blowing engines; diameter of steam-cylinder, 42 inches; blowing cylinder, 84 inches; and stroke, 4 feet. This type of blowing engine is among the foremost in the United States for strength, efficiency, and durability, each engine having a maximum capacity of pumping 12,000 cubic feet of air per minute of piston displacement. The pumps are of the Cameron type; two for water supply, and two for filling boilers.

The engine-house is roofed with a sway-bottomed water tank, resting merely on the walls of the engine-house, without any other support, which is kept filled with water at all times for the supply of the entire plant. It is 6 feet deep in the centre, and the surface of the water is 42 feet 6 inches above the hearth level, or engine foundation.

The casting-house is 138 x 50 feet, outside measurement, and the stock-house 75 x 150 feet. Both these buildings are roofed with

corrugated iron, as is also the hoist-tower and bridge connecting it with the furnace. The hoisting apparatus is of the Crane Brother system, of Chicago, and the superstructure is wrought-iron channel beams.

This furnace has a cubical capacity of about 9,000 feet, and when worked up to its reasonable output, under intelligent management, will have a producing capacity of fully 100 tons per day, and can be worked up to 1000 tons per week, if the manager so determine, on an ore containing 50 per cent. of metallic iron, with silica not exceeding 6 to 8 per cent., at a temperature of blast ranging from 1400 to 1600 degrees Fahrenheit.

We would submit the following formulas, which we use in determining the capacity or output of a furnace; also, in determining the size of its boiler, engine, and draught-stack.

We allow, for anthracite furnaces, 60 square feet of fire surface in boilers to produce a ton of iron in twenty-four hours; therefore, 6000 feet of fire surface will supply steam to make 100 tons of iron in twenty-four hours. For coke furnaces we allow 40 square feet of heating surface for a ton of iron in twenty-four hours, or 4000 square feet for 100 tons of iron in twenty-four hours; and for charcoal furnaces we give 30 square feet for a ton of iron in twenty-four hours, or 3000 square feet for 100 tons of iron in twenty-four hours. This is assuming that the heat of the blast will range from 1300 to 1500 degrees Fahrenheit.

By the same method we have determined that 140 feet of air per minute of piston displacement will make a ton of iron in twenty-four hours, with 50 per cent. ores, if not too highly siliceous, at a temperature of blast above given; therefore 14,000 feet per minute will make 100 tons of iron in twenty-four hours. For charcoal furnaces, on the same ores and at the same temperature, we calculate 110 feet per minute to make a ton of iron, therefore 11,000 feet per minute will make 100 tons of iron in twenty-four hours. We assume that the chimney or smoke-stack must have a capacity of carrying off 15 tons of gas (or products of combustion) for every ton of iron the furnace is expected to make.

In deciding on the amount of limestone necessary for a blast furnace (apart from the analysis of the cinder) we have found it a good approximate rule to make the amount of lime (*i. e.*, the limestone less the carbonic acid) equal to the sum of the amounts of silica in the ores, limestone, and fuel. If more lime is used it is injurious to good furnace action. It also saturates the escaping gases with an

excess of carbonic acid, which lessens their calorific power. A furnace works sluggishly on an excess of lime, and is apt to scaffold.

Blowing-in.—The filling was done by using some 15 cords of wood, on which was put about 15 tons of coke, and then the burden commenced by using 3000 pounds of coke, 1000 pounds of ore, and 800 pounds of lime. This was continued by slightly increasing the ore and lime until the furnace was filled. On Monday evening, May 28th, at 6 o'clock, the furnace was lighted by Miss Margaret Crozer, and the furnace given her name. At 1 o'clock P.M., the following day (Tuesday), the blast was applied, and the waste gases of the furnace descended the down-comer, traversed the large horizontal blast-tube, flowed under the boilers and the Whitwell stoves, without the least explosion or even the faintest puff.

There was a difference of opinion with regard to the introduction of fire into the gas flue some time before applying the blast. I maintain that a wood fire should be put in the flue, and I would be glad to submit this question to furnace-men.

The operations of the furnace went off satisfactorily. The hearth, however, was too cold for the reception of the ore. It would have been better, I think, to have put in from 3 to 5 cords of wood, just sufficient to thoroughly ignite the coke, then about 30 tons of coke, and commence with a burden of 3000 pounds of coke, 3000 pounds of ore, and 1200 of lime, continuing this burden until the furnace was filled. As soon as the blast went on, I would have charged 3000 of coke, and 4000 of ore, and the same proportion of lime. I maintain this is the proper way of blowing in a furnace. The use of a large quantity of cord-wood, with a small proportion of fuel on the top, and the burdening of a small proportion of ore to fuel, is not good practice, because the wood rapidly consumes, allowing the space that it occupied to be replaced by coke and the furnace burden. Then the small quantity of ore is brought very near the tuyeres, before the blast goes on, and before the hearth is thoroughly heated; consequently this ore has a tendency to chill and settle in the bottom, if the furnace is not fortified by the Whitwell stoves. Where a smaller quantity of wood, and a larger proportion of coke is put on, with a greater burden, the hearth is filled with incandescent coke, and liquefaction is retarded until the hearth is in a condition to receive the iron and cinder. The regular process begins on a large scale, the hearth becomes filled with hot cinder, the process of combustion goes on steadily, and the heat in the stoves is gradually increased; so that no matter how dark the cinder may be for the first

day, which is most desirable, the heat will develop more rapidly than the burden can be increased. Within three days the temperature of the stoves must be reduced, or the cold blast put on, so as to keep down the heat, to prevent the iron becoming too gray or silvery. A furnace supported with superheated blast should, therefore, always be blown-in on a reasonably heavy burden, and the manager should desire dark cinder for the first two days, and gradually increase his ore burden until he is satisfied that the proper proportions are on the furnace.

The Whitwell stoves are frequently blamed for the bad working of furnaces, and for unsatisfactory results in an economical point of view, when the whole trouble is in the management. The old practice of blowing-in furnaces is still not unfrequently adopted, that is to say, a great excess of fuel and everything calculated to produce a very gray cinder, and a No. 1 or No. 2 foundry iron at the start. This is not good practice. An excess of fuel is resorted to for the purpose of making the furnace very hot, and may be justified in cold-blast charcoal practice. Where the heat of the blast ranges from 500 to 800 degrees with iron-pipe stoves (commencing at 100 or 200 degrees), there may also be some reason for continuing the old practice. In modern practice, where the furnaces are supported with superheated blast, the fallacy of such a course has been demonstrated, and it is surprising to see it still pursued. This course is often maintained long after the furnace is in blast, and as the heat of the stoves augments in a greater ratio than the increase of burden, the carbonic oxide has little to do in the zone of combustion or the region of the tuyeres, and as the gaseous currents ascend in the furnace, they establish partial liquefaction and cementation in the upper regions of the bosh, often continuing this action up the inwalls, causing scaffolding and bridging. With such a course, especially in anthracite furnaces, the blast is bound to be a failure, as the removal of such obstructions is difficult and rarely effected.

I think that blast-furnace engineers should establish a system of running the furnace by the temperature of the escaping gases. This temperature indicates the changes more quickly than the cinder or the iron. Other things being equal, the hotter the blast the cooler the top, and *vice versa*, and the increase of temperature at the tunnel-head will sooner indicate to the manager a derangement in furnace action than anything else. As the temperature of the higher zones increases, it will show that there is either an inadequate amount of ore and lime for the ascending gaseous currents and carbonic oxide

to act upon, or it will show that the furnace is beginning to cement and scaffold, and prompt measures can be taken to remedy the difficulty.

Postscript.—The amount of foundry iron weighed to-day for yesterday's output was 77 tons, which is the fifth day of the furnace's operations. The fuel is very close to a pound of iron with a pound of coke, the furnace being under a burden of nearly 2 pounds of ore to 1 of coke, and the ore yielding over 50 per cent. metallic iron. This indicates that within a few days this furnace may be making over 100 tons of iron per day, on a fuel consumption not exceeding a pound of coke to a pound of iron.

POROSITY AND SPECIFIC GRAVITY OF COKE.

BY FRED. P. DEWEY, WASHINGTON, D. C.

ALTHOUGH coke is the acknowledged metallurgical fuel, and has been extensively used in this country for more than thirty years, yet the facts on record in regard to its physical properties are exceedingly meagre; and this is also true, but in a less degree, of its chemical composition. An investigation is being carried on in the National Museum which is intended to supply, so far as may be, this deficiency, and through the kindness of Professor Baird, Director of the Museum, I am permitted to present to the Institute a summary of a portion of the results already obtained.

So far as I am aware, the credit for the first systematic investigation of the physical properties of coke belongs to Mr. John Fulton, Mining Engineer of Cambria Iron Co. The results of this investigation have been published in Report L, Second Geological Survey, Pennsylvania, 1875, and in a pamphlet setting forth the advantages of the Connellsville coke, the latter published also by the "*Virginias*."* His results are not altogether free from experimental errors, and the assumption that "the specific gravities of coke and water are very nearly alike"† is scarcely warranted. It has seemed to me, therefore, desirable to make an independent investigation of the physical properties of coke on a plan somewhat different from that adopted by Mr. Fulton. This is the investigation now being carried on at the National Museum.

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* *Virginias* (Staunton, Va.), 1883, p. 40.

† Second Geol. Survey of Penna., Report L, p. 130.

In the present communication it is intended to give only results relating to the specific gravity and the amount of cells or pores in the coke. At some future time it is intended to supplement this by determinations of the resistance to crushing and abrasion and by microscopic examination, and an attempt will also be made to answer the old, but still unsolved, question of why one coal will coke and another will not.

One of the prime factors upon which the superiority of coke as a metallurgical fuel rests, as already pointed out by Mr. Fulton, is its porosity, permitting, as it does, the very easy penetration of the gases of the furnace to its very centre, causing thereby its very rapid combustion at the tuyeres, and consequently maintaining the required degree and amount of heat. The determination of the porosity of coke possesses therefore a very decided practical value aside from its scientific interest. But no estimation of the practical value of a coke can be made from a determination of porosity by itself, for, while the possession of a certain amount of cell space is very desirable and necessary, yet a limit is set upon it, and any increase beyond that limit decreases the practical value of the coke. This limit is reached when the cell walls become so thin that the coke is unable to bear the burden in the furnace, and varies, of course, with different cokes; in some the porosity is far too great to leave sufficient material in the cell walls to give them their needed strength.

The method used in determining the specific gravity, porosity, etc., is founded upon the simple and elegant method proposed by Dr. T. Sterry Hunt.* The older and more generally followed method of using an accurately-cut cube involves the expenditure of far more labor to secure exactness than is justified, and it is unfortunate that this method proposed by Dr. Hunt should not be more generally known and used.

The method, in brief, is to take fragments of any suitable size or shape, and, after weighing them in air, to thoroughly fill their pores with water. Then two weighings—one in water and one in air—will give all the data necessary for finding the volumes of the specimens, and this is accomplished with far more ease than the cutting of a cube. These three weighings give all the data necessary for determining the following points: True specific gravity, or the actual specific gravity of the coke; the apparent specific gravity, or the relationship between the entire volume of the coke and an equal volume of water; the percentage, by volume, of cells in the coke

* Chemical and Geological Essays, T. Sterry Hunt, p. 164.

and volume of cells in a given weight. In experimenting with coke, however, its nature necessitates a few changes in the proceedings as laid down by Dr. Hunt, and I will describe my method in detail.

Suitable specimens from 20 to 40 grams in weight were selected to represent the average physical condition of the coke. These were weighed as they were received; they were then dried at a temperature of 100° C. for one hour, and then cooled under the desiccator and weighed, the loss in weight representing the amount of moisture in the specimen as received. The next point was to fill the pores or cells with water, and after considerable experimenting the following general plan was adopted, which was modified in its details to suit particular cases.

It was found more expedient to use a combination of the two methods usually adopted to fill porous substances with water, viz., the use of the air-pump and boiling. The specimens were placed in water and allowed to remain from 12 to 24 hours; they were then placed under the receiver of an air-pump and the air exhausted; the exhaustion was repeated from three to five times. The specimens were then removed and placed in boiling water and boiled for three hours. After becoming nearly cold they were again placed under the receiver of the air-pump and exhausted, and the exhaustion repeated at intervals of 10 to 20 minutes, until no more bubbles were seen to come off; as a precaution, they were further exhausted from six to eight times to insure as complete as possible removal of the air. Owing to the nature of the case, it is not possible to replace the very last traces of air by water, and, in order to determine the probable error from this cause, 18 specimens were again subjected to a varying number of exhaustions, amounting in one case to 20, and it was found that the average gain in weight represented only 0.34 per cent. of the true volume of the coke experimented upon, an error sufficient to cause but a very slight change in the specific gravity.

The specimens thoroughly saturated with water, were weighed first in water and then in air. The directions laid down by Dr. Hunt, and the plan generally followed in determinations of porosity, to dry the surface of the specimens with bibulous paper or some other absorbent of water, could not be followed in this case, for, owing to the large percentage of pores in the coke, and to the slight adhesion of water to their surfaces, it was found that on applying any absorbent material, the water would not only be removed from the surface, but withdrawn from the pores themselves. It was therefore decided that the most feasible plan would be to remove the

specimens from the water and allow as much water as would to drain off; they were then weighed as rapidly as possible. By this proceeding a double error is induced—first, a plus error from the thin film of the water adhering to the surface of the coke, and, secondly, a minus error from the water flowing out of the pores opening upon the surface. These errors will, in a measure, balance each other. It is necessary to take this weight as rapidly as possible, for the evaporation from the surface of the coke is very rapid and it takes but a few moments for a specimen to lose 10 mg. In order to determine the probable error of weighing these wet specimens, 33 specimens were weighed and again immersed in water, and after standing 12 hours were taken out and weighed again. Of these 33 specimens, 25 gained weight and 8 lost, the average gain being .14 per cent. of the total volume of the coke, and the average loss was .1 per cent. In the determination of the specific gravity there are two sources of variation, one inherent in all specific gravity determinations and unavoidable, and the other accidental and in a measure disappearing in the averages. The first error is due to the possible presence of water-tight pores, or cells, causing a minus error in the determination. The other error is due to the possible presence in a piece of coke of a small piece of slate causing a plus error. The first or minus error applies also to the porosity determination, but its effect is far less in that case than it is upon the specific gravity determination, for in the first case the result is only affected by the actual volume of the water-tight cells, while in the second case, aside from this, the determination is affected by the buoyancy imparted to the specimen by the inclosed air or other gas.

In carrying out this investigation, 153 specimens of coke have been examined, representing 11 localities producing metallurgical coke, and one gas-works coke; in all cases but one, 12 specimens were selected to represent the locality; the exception, Connellsville, is represented by 21 specimens. The results given are reduced to the temperature of the maximum density of water (4° C.), and embrace the maximum and minimum determinations in each set, and also the average of the 12 determinations of the following points: Moisture; true specific gravity, or the actual specific gravity of the coke; apparent specific gravity, or the relationship between the whole volume (including the coke and the cells) and an equal volume of water; the percentage of cells by volume, and the volume of cells in a given weight of coke (cubic centimeters in 100 grams). But it must be borne in mind that although the determinations are given in a line for convenience, yet it does not follow in every case that

related results are obtained from the same specimens—that is to say, while in some cases the maximum apparent specific gravity and the minimum percentage of cells given are the results from the same specimen, yet it is not always so; for, in following out the relationship between the results, it is necessary that all the determinations of a specimen should be taken into consideration, and in some cases the results on different specimens, in one or more determinations, will agree within the probable error of determination.

No. 1.—A suite of 9 samples of coke shipped to the Crozer Furnace, at Roanoke, Va., from the Broadford Works of Frick & Co., Connellsville, Pa. Analyses of the coal from which this coke was made, and also of the coke, are as follows:

	Lump Coal *	Slack Coal.*	Coke †
Water,	1.260	0.950	0.030
Volatile matter,	30 107	29.662	0.460
Fixed carbon,	59.616	55 901	89.576
Sulphur,	0.784	1.931	0.821
Ash,	8.233	11.556	9 113
Total,	100 000	100.000	100 000
Color of ash	Reddish grey.	Reddish grey.	
Coke, per cent.,	68.633	69.388	

Analyst, McCreath.

This coke was made in ovens of the beehive pattern, according to the usual method of the Connellsville region‡, and the sample taken by Mr. J. H. Bramwell.

Coke.—Connellsville, Broadford—Frick & Co.

	Moisture.	True specific gravity.	Apparent specific gravity	Per cent. of cells by volume.	C. C. in 100 grams.
Maximum,	0 096	1.79	1 033	54 37	66.31
Minimum,	0.008	1 73	0 819	42.20	40 83
Average (9),	0.034	1.76	0.892	49.37	55.73

No. 2.—A suite of twelve specimens given in full to represent the Connellsville region, three specimens each being taken from the product of the following works: First, Morrell ovens; second, H. C. Frick & Co.; third, Schoonmaker & Co.; fourth, J. F. Dravo. An

* Second Geological Survey, Pennsylvania, Report M M, page 22.
† Ibid., Report M M, page 107.
‡ Ibid., Report L, page 63.

analysis of the Pittsburgh seam of coal at Connellsville, from which this coke was made, is as follows:

Fixed carbon,	59 62 *
Ash,	8 23
Volatile matter,	31.36
Sulphur,	0 784
Total,	99.994

Coke, 68 per cent.

These specimens were furnished by Mr. John Fulton, and may fairly be taken to represent the coke of the Connellsville region, analyses of which are given below:

	J. F Dravo.	J. F. Dravo.		
Water,	0 040†	0 110†		
Volatile matter,	0.352	0.471		
Fixed carbon,	88 906	88.403	87.46 ‡	87.26 ‡
Sulphur,	0.771	0 838	0 69	0.746
Ash,	9.931	10 178	11.32	11 99
Total,	100.000	100 000		

The samples were selected by Mr. John McFadyen.

Connellsville Coke.

No. 1.—Morrell Ovens.

Moisture	True sp gr.	A. sp gr.	Per cent of cells by volume	C C in 100 grams.
0.020	1 65	0 716	56 61	78 90
0 017	1.80	1 007	44.02	43 69
0.065	1.74	0.990	43.23	43.66

No. 2.—H. C. Frick & Co.

Moisture.	True sp. gr.	A sp gr.	Per cent of cells by volume.	C C. in 100 grams.
0 011	1.69	1.016	40 04	39.05
0.339	1 69	0 880	47.88	54.39
0.046	1.67	0.873	47 65	54.58

* Analyst, T. T. Morrell, Second Geological Survey, Pennsylvania, Report L, page 120.

† Analyst, McCreath, Second Geological Survey, Pennsylvania, Report M M, page 107.

‡ Analyst, ——, Second Geological Survey, Pennsylvania, Report L, page 133.

No. 3.—Schoonmaker & Co.

Moisture.	True sp gr	A. sp gr.	Per cent of cells by volume.	C C in 100 grams
0.023	1 83	1.119	38 76	34.62
0 016	1.82	0.900	50 43	56.03
0 023	1.81	1.054	41.94	39.79

No. 4.—J. F. Dravo.

Moisture.	True sp gr.	A. sp gr.	Per cent of cells by volume.	C C in 100 grams.
0.012	1.69	0.979	42 33	43 23
0 025	1 78	0.837	52.99	63.27
0.042	1 73	0.743	57.21	77.04

Average.	Moisture.	True sp gr.	A. sp gr	Per cent. of cells by volume	C C in 100 grams.
Maximum, . . .	0.339	1.83	1.119	57.21	78.90
Minimum, . . .	0.011	1.65	0.716	38.76	34.62
Average (12), . .	0.053	1.74	0.926	46 92	52 35

No. 3.—A suite of twelve specimens, from the Eagle Ovens, Kanawha, West Virginia. This coke was made in beehive ovens, from middle measures coal, and the samples furnished by Mr. T. Wharton.

Coke.—Eagle Ovens, West Virginia.

	Moisture.	True sp gr.	A. sp. gr.	Per cent. of cells by volume.	C. C. in 100 grams.
Maximum, . . .	0.074	1.74	0.979	58.14	86.54
Minimum, . . .	0.006	1.60	0 672	41.39	42.66
Average (12), .	0 021	1.68	0 894	46.85	53.89

No. 4.—A suite of twelve specimens, from the St. Clair Ovens, West Virginia. This coke was made in ovens of the beehive pattern, from middle measures coal, and the samples taken by Mr. Thomas Wharton.

Coke.—St. Clair Ovens, West Virginia.

	Moisture.	True sp gr.	A. sp. gr.	Per cent. of cells by volume.	C. C in 100 grams
Maximum, . . .	0.070	1.77	1.125	53.91	74 61
Minimum, . . .	0.008	1.57	0.723	36.25	32 21
Average (12), . .	0.030	1.67	0.924	44.81	50.23

No. 5.—A suite of twelve samples, from the Quinnimont Furnace, Fayette County, West Virginia. The composition of the coal (samples taken from the different headings) from which this coke was made, and also of the coke, is as follows:

	Coal.				Coke
Water, ...	0 45	0 44	0 38	0.36	. . . .
Fixed carbon, . .	77.97	77.74	74.90	76.89	92 62
Volatile matter, .	18.99	20 06	20 15	20 76	. . . .
Ash, ...	2.03	1 17	3.21	1 35	7.23
Sulphur, ...	0 56	0 59	1.36	0.64	0.665
Phosphorus, . . .	. . . .	. . . .	. . . .	. . . .	0.050
Total, ...	100.00	100.00	100.00	100.00	. . . .

Analyst, Professor Thomas Egleston.

This coal is from the New River or lower measures. This coke is made in ovens of beehive pattern, 9 feet 6 inches, 10 feet 6 inches, and 11 feet 6 inches in diameter and 6 feet high, the charge being 6800 to 8500 pounds. The average yield for a year's working is 64.75 per cent. of the coal charged, and the average of six months is 65.25 per cent.; it is used in the Quinnimont Furnace, 60 × 16 feet, and carries a burden of 2.2 pounds to 1 pound of coke. For the above analyses and figures I am indebted to Mr. J. F. Lewis, general manager. The sample was taken by Mr. Stiles Hotchkiss from four carloads of forty-eight-hour coke.

Coke.—Quinnimont, New River District, Fayette County, W. Va.

	Moisture.	True sp gr.	A. sp gr.	Per cent of cells by volume	C C in 100 grams.
Maximum, . . .	0.076	1.92	0.791	66.98	105.49
Minimum, . . .	0.010	1.77	0 639	55.93	70.75
Average (12), . .	0.044	1.83	0.713	61.12	86.41

No. 6.—A suite of twelve samples, from the coke ovens of Longdale Iron Company, at Sewell, Fayette County, West Virginia. This coke was made from lower measures coal. The composition of the coal and coke is as follows:

	Coal.	Coke.
Water, ...	1 03	. . . .
Volatile matter, ...	21.38	. . . .
Fixed carbon, ...	72.32	93 00
Ash, ...	5.07	6 73
Sulphur, ...	0 20	0 27
Total, ...	100.00	100.00

Analyst, C. E. Dwight (American Institute Mining Engineers, vol. viii, pages 266 and 267).

This coke was made in beehive ovens 13 feet × 6 feet, the charge being 12,000 pounds and the yield 62 per cent.; the time of coking 48 and 72 hours. This coke is used in the Lucy Selina Furnace of the Longdale Iron Company, 60 feet × 11 feet, carrying a burden of 2.726 pounds to one pound of coke.* The sample was taken by Mr. J. C. McGuffin.

Coke.—Sewell, New River District, Fayette County, W. Va.

	Moisture.	True sp. gr.	A. sp. gr.	Per cent of cells by volume.	C. C in 100 grams.
Maximum, . . .	0.033	.1.74	0.891	55.79	74.30
Minimum, . . .	0.007	1.66	0.750	46.41	52.08
Average (12), . .	0.016	1.69	0.703	53.19	67.39

* Journal United States Assoc. Charcoal Iron Workers, vol. ii, p. 371, No. 2 of table.

No. 7.—A suite of twelve specimens, from Stone Cliff, Fayette County, West Virginia. This coke is made from lower measures coal in beehive ovens, 11 feet 6 inches × 6 feet, the charge being 9000 for forty-eight-hour and 10,000 for seventy-two-hour coke. The sample was taken by Mr. N. M. Jenkin.

Coke.—Stone Cliff, New River District, Fayette County, W. Va.

	Moisture.	True sp. gr.	A. sp gr	Per cent of cells by volume.	C. C in 100 grams.
Maximum, . . .	0.119	1.79	0.962	57.60	77.85
Minimum, . . .	0.039	1.66	0.740	46.20	50.14
Average (12), . .	0 074	1.74	0.838	51.79	62 30

No. 8.—A suite of twelve specimens, from the Fire Creek Ovens, Fayette County, West Virginia. This coke was made in ovens of the beehive pattern, from lower measures coal. The composition of the coal and coke is as follows:

	Coal *	Coke.†	Coke.‡
Moisture, ...	0 61	0 216	0.11
Volatile matter, ...	22.34	0 390	0.35
Fixed carbon, ...	75 02	95.894	92.18
Ash, ...	1.47	3 500	6 68
Sulphur, ...	0.61	0 563	0.618
Phosphorus, ...	. . . .	0 0096	0.027

The specimens were selected by Stiles Hotchkiss.

Coke.—Fire Creek, New River District, Fayette County, W. Va.

	Moisture.	True sp gr.	A. sp. gr.	Per cent. of cells by volume.	C. C. in 100 grams.
Maximum, . . .	0.161	1 88	0.897	70 10	126.58
Minimum, . . .	0.024	1.78	0.554	49.99	55.74
Average (12), . .	0.078	1.83	0.820	55.12	69.05

* Transactions American Institute Mining Engineers, vol. viii, page 267.
† Virginias, 1883, page 99. Analyst, Dr. Henry Frœhling, April 3, 1883.
‡ Virginias, 1883, page 41. Analyst, J. B. Britton, March 3, 1879.

No. 9.—A suite of twelve specimens, from the works of the Roane Iron Company, at Rockwood, Tennessee. This coke was made from upper measures coal of the following composition:

Water,	1 75	1.39
Volatile matter,	26 62	32.59
Fixed carbon,	60.11	60.75
Ash,	11.52	5.27
Total,	100.00	100.00
Sulphur,	1.49	
Analysts,	Dewey.	Duncan.

This coke was made in beehive ovens, 11, 12 × 13 feet diameter, and 6 feet high, the charges being 100 bushels. The coking occupies forty-eight hours. It is used in the two furnaces of the Roane Iron Company, at Rockwood, 65 × 16 feet and 65 × 14 feet, and carries a burden of 2.29 pounds to one pound of coke. I am indebted to Mr. M. M. Duncan, assistant superintendent, for the above figures and samples.

Coke.—Rockwood, Tenn.

	Moisture.	True sp. gr.	A sp. gr.	Per cent of cells by volume.	C. C in 100 grams.
Maximum,	0 436	1.75	1.075	51.99	61.95
Minimum,	0.031	1.63	0.839	38.72	36.03
Average (12),	0 192	1.69	0.935	44.81	48.55

No. 10.—A suite of twelve specimens, from the El Moro works of the Colorado Coal and Iron Company. The coal from which this coke was made occurs in the Laramie formation, which lies at the boundary between the Cretaceous and Tertiary, and is of the following composition:

Water, at 110° C.,	1.14
Volatile matter,	29.97
Fixed carbon,	56.32
Ash,	12.57
Total,	100.00

Sample of a carload.
Analyst, Wells.

This coke is made in ovens of the beehive pattern, 11 feet 6 inches × 6 feet, the charge being 4.2 tons, and the yield 60 to 65 per cent., and time of coking forty-eight hours.

The amount of ash, as shown by about forty analyses by Mr. Wells, is 18 per cent., and the percentage of silica in the ash 12 per cent.; the sulphur is from .46 to .53 per cent.

The coke is used in the furnace of the Colorado Coal and Iron Company, at South Pueblo, Colorado, 65 feet × 15 feet, carrying a burden of two pounds to one pound of coke.

Coke.—El Moro, Colorado.

	Moisture.	True sp gr.	A. sp gr.	Per cent. of cells by volume	C C in 100 grams.
Maximum, . . .	0.225	1.85	1.047	54.66	71.36
Minimum, . . .	0.025	1.61	0.766	41.47	41.56
Average (12), . .	0.114	1.69	0 919	45.75	50.39

No. 11.—A suite of twelve specimens, from the Crested Butte Works of the Colorado Coal and Iron Company. The coal from which this coke was made occurs in the Fox Hill group of the Cretaceous of the following composition:

Water at 110° C.,	0.72
Volatile matter,	23.44
Fixed carbon,	71.91
Ash,	3.93
Total,	100.00
Sulphur,	0.36

Sample average of entire face of seam, 7 feet thick.
Analyst, Wells.

This coke is made in ovens of the beehive pattern, 11 feet 6 inches × 6 feet, the charge being about 3.75 tons, and the yield about 70 per cent. The time of coking is 48 hours.

The amount of ash, as shown by six analyses by Mr. Wells, is 8.7, the percentage of silica in the ash being 4.6 per cent.; the sulphur is from 0.37 to 0.58 per cent. This coke is used by lead smelters, and in cupolas, etc., in Colorado.

Coke.—Crested Butte, Colorado.

	Moisture.	True sp gr.	A. sp gr.	Per cent of cells by volume.	C C in 100 grams.
Maximum, . . .	0.171	1.62	0.968	47.01	55.48
Minimum, . . .	0.011	1.53	0 848	37.39	38.63
Average (12), . .	0.073	1.59	0.907	42.96	47.59

The samples for this and the preceding determinations were taken by Mr. John Cameron, general superintendent of the coal mines. I am much indebted to the Colorado Coal and Iron Company for kindness in furnishing samples and information, and especially to Mr. H. L. Wells, chemist.

No. 12.—A suite of twelve specimens, from the Leetonia Works of the Cherry Valley Iron Company, Columbiana County, Ohio. The coal from which this coke was made—the Lower Kittanning Seam of Pennsylvania, which occupies but a small space in Ohio—is of the following composition:

Water,	3.00
Volatile matter,	31.50
Fixed carbon,	62.35
Ash,	3.15
Total,	100.00
Sulphur,	1.40
" left in coke,	0.60
" of coke,	0.92
Specific gravity,	1.274

Sample from Salem shaft, bottom bench.
Analyses from Professor Edward Orton.

The coal seam is about 30 inches thick, the upper 6 inches being non-coking, and used in the furnace in its raw state. This coke was made in ovens of the beehive pattern, 12 × 6 feet, occupying 72 hours in the coking. It is used in the furnaces of the Cherry Valley Iron Company at Leetonia, 75 feet × 16 feet, and 55 feet × 14 feet. In the large furnace it carries a burden of about two pounds to one pound of coke. The sample was furnished by Professor Edward Orton, and I am indebted to Mr. J. G. Chamberlain, superintendent of Cherry Valley Iron Works, and Professor Edward Orton for specimens and information kindly furnished.

Coke.—Leetonia, Columbiana County, Ohio.

	Moisture.	True sp. gr.	A. sp. gr.	Per cent. of cells by volume.	C C in 100 grams.
Maximum, . . .	0 142	1.55	0 844	52.83	74.06
Minimum, . . .	0.012	1.46	0.706	36 06	42.71
Average (12), . .	0.047	1.49	0.770	47.59	62.23

No. 13.—A suite of twelve specimens from the Washington City Gas Light Company, are added for the sake of comparison. This coke is such as is sold by the company for domestic uses, and has been crushed and washed. Consequently, it shows in some cases a high percentage of water; it also shows, as might be expected from the method of its manufacture, wide variations in all the determinations.

Coke.—Washington Gas Works.

	Moisture.	True sp gr.	A sp gr.	Per cent of cells by volume.	C C in 100 grams
Maximum, . . .	2.529	2 07	0.911	66.39	133.49
Minimum, . . .	0 179	1.48	0.497	46.59	51.84
Average (12), . .	0.802	1.74	0.772	55.66	75.48

The above results are put on record without drawing any conclusions therefrom. While they are interesting and instructive, yet the investigation is but fairly commenced, and conclusions drawn now may be materially changed by subsequent examinations. There is, perhaps, no subject upon which more erroneous conclusions have been drawn from entirely insufficient and often imperfect data than that of coke, and it is especially desired to avoid anything of the kind in this investigation. It is intended to make the examination sufficiently extended to embrace a large number of determinations of all the important characteristics of coke, so that it will furnish a basis for forming reliable conclusions in regard to the uses and value of coke.

For the sake of convenience in comparison a table is added, showing all the important information at present accessible in regard to the cokes examined.

Number.	Locality of Coke Works.	COKE.—SPECIFIC GRAVITY, POROSITY, ETC AVERAGE. Moisture.	True sp. gr.	Apparent sp gr.	Per cent of cells by volume.	Volume of cells in 100 grams cc.	Weight per cubic foot. Pounds.	Sampled by	COAL—GEOLOGICAL POSITION AND ANALYSES. Geological formation.	Water.	Volatile matter	Fixed carbon.	Ash.	Sulphur	Analyst.
1	Broadford, Connellsville, Pa	0 034	1.76	0.892	49 37	55 78	55 68	J. H Bramwell.	Pittsburgh bed	1 105	29 885	57 754	9 895	1.339	McCreath
2	Connellsville, Pa	0 053	1 74	0 926	46 92	52 35	57 81	J McFadyen	Pittsburgh bed		31 36	59 62	8 23	0 781	T. T. Morrell
3	Eagle, Kanawha, W Va	0 021	1 68	0 894	46 85	53 89	55 81	T. Wharton.	Middle measures (XIII)						
4	St Clair, Kanawha, W. Va	0 030	1 67	0 924	44 81	50 23	57 68	T Wharton	Middle measures (XIII),						
5	Quinnimont, New River	0 044	1 83	0.713	61.12	86 41	44 51	S. Hotchkiss	Lower measures (XII)	0 41	19 99	76 87	1 94	0 79	T Egleston
6	Sewell, New River, W. Va	0.016	1 69	0 793	53.19	67 39	49 50	J C. McGuffin	Lower measures (XII)	1 03	21 38	72 32	5 07	0 20	C E. Dwight
7	Stone Cliff, New River, W Va	0 074	1 74	0 838	51 79	62 30	52 31	N M Jenkin	Lower measures (XII).						
8	Fire Creek, New River, W. Va	0 078	1 83	0 820	55 12	69.05	51 19	S Hotchkiss	Lower measures (XII),	0 61	22 34	75 02	1 47		
9	Rockwood, Tenn	0 192	1 69	0 935	44.81	48 55	58.37	M M Duncan	Upper meas'rs (XIV–XV)	1 75	26 62	60 11	11 52	1 49	Dewey.
10	El Moro, Col	0 114	1 69	0 919	45 75	50 39	57 37	J Cameron	Laramie formation	1 14	29 97	56 32	12 57		Wells.
11	Crested Butte, Col	0.073	1 59	0 907	42 96	47 59	56 62	J Cameron.	Fox Hill group	0 72	23 44	71 91	3 93		Wells.
12	Leetonia, Ohio	0 047	1 49	0 770	47 59	62 23	48 09	E. Orton.	Lower Kittanning Seam.	3 00	31 50	62.35	3.15	1 40	
13	Washington Gas Works, D C.	0 802	1 74	0 772	55.66	75 48	48 19	Dewey							

Number.	COKE.—ANALYSES OF. Water.	Volatile matter.	Fixed carbon	Ash.	Sulphur.	Phosphorus	Analyst.	COKE—METHODS OF MANUFACTURE Style of oven	Size.	Charge Pounds	Yield Per cent	Time of coking. Hours.	COKE—USED FOR. Kind of Furnace.	Size of Furnace.	Pounds burden to 1 lb coke
1	0 030	0 460	89 576	9 113	0 821		McCreath.	Beehive	11′ x 5′ 6″, 12′ x 6′	7,600	63	48 and 72	Iron blast	70′ x 16′	
2	0.075	0 412	88.655	10.035	0 805		McCreath	Beehive	11′ x 5′ 6″, 12′ x 6′	7,600	63	48 and 72	Iron blast, etc		
3								Beehive							
4								Beehive							
5			92 62	7.23	0 665	0.050	T. Egleston	Beehive	9′ 6″, 10′ 6″, 11′ 6″ x 6′	6,800 to 8,500	65	48	Iron blast	60′ x 16′	2 2
6			93.00	6 78	0 027		C. E Dwight.	Beehive	13′ x 6′	12,000	62	48 and 72	Iron blast	60′ x 11′	2.726
7								Beehive	11′ 6″ x 6′	9,000 to 10,000		48 and 72			
8	0.216	0 390	95 894	3.500	0.563	0.0096	H Froehling	Beehive							
9								Beehive	11′, 12′ and 13′ x 6′	100 bushels		48	Iron blast	65′ x 14′, 65′ x 16′	2 29
10				18 00	0.50		Wells.	Peehive	11′ 6″ x 6′	4 2 tons	60 to 65	48	Iron blast	65′ x 15′	2
11				8.70	0.48		Wells.	Beehive	11′ 6″ x 6′	3 75 tons	70	48	Lead smelters, etc		
12								Beehive	12′ x 6′			72	Iron blast	75′ x 16′	2
13								Retorts					Domestic		

Note.—Of the above No 1 is the average of nine determinations, and the others of 12, for specific gravity, porosity, etc., of the coal analyses No 1 is the average of two analyses and No. 5 of four—of the coke No 2 and the sulphur in Nos. 10 and 11 are the averages of two analyses.

BIOGRAPHICAL NOTICE OF LOUIS GRUNER, INSPECTOR-GENERAL OF MINES OF FRANCE.

BY T. EGLESTON, PH.D.

I HAVE to announce with great regret that our distinguished honorary member, Louis Gruner, died in Paris in March last. The Institute, in his death, has lost one of the first as well as one of the greatest of its honorary members. I speak with great feeling, as he was both my instructor and my friend; and I am sure that if he could hear what I am about to say of him, he would object to it. Mr. Gruner's modesty was such as even to prevent, except in his own Corps, the thorough appreciation of his work in his own country. I think he was better appreciated by those who are familiar with his labor in almost any other country than his own. A just man, a thorough scholar, a great investigator, he was so unselfish that almost the last act of his life, and the last letter he signed, only a few hours before his death, had for its object to render a service to one of his former pupils. I think no one who was ever associated with him could forget, in the greatness of his learning, the sincere and earnest friend, who was always ready to render a service, where such service could be rendered even at great inconvenience to himself. His own motto, "Sein, nicht schein;" that is, "Be, not appear to be," was singularly descriptive of his character; and, what is more than all, he was one of the most earnest Christian men with whom it has ever been my good fortune to be thrown in contact. There are few such men. He was one of the greatest metallurgists that Europe has ever produced; a man the more remarkable because, though known to most of us as a metallurgist, some of the best work of his life was in the domain of geology, to which he contributed very important researches and memoirs, which will remain permanently among the valuable additions to the geology of his own country. He was, at the same time that he was the greatest metallurgist in Europe, a brilliant chemist, a thorough geologist, a distinguished professor, and an expert, practical miner, whose advice and methods had only to be known to be followed.

Mr. Gruner was born in Switzerland in 1809, and graduated from the Polytechnic School of Paris in 1830 and entered the School of Mines, from which he graduated with distinction in the Corps of Government Engineers of Mines at an early age, and was immedi-

ately sent to travel in Germany. Shortly after his return he commenced to prepare himself for the professorship of Chemistry and Metallurgy in the School of Miners at St. Étienne, which position he occupied from 1835 to 1847.

At the very beginning of his professional career he commenced the publication of observations and researches of great value to the profession, in the *Annales des Mines*, and these he continued to publish to the end of his life. In 1841 he began his researches on the geology of the Loire, which were not completed until 1857, when he published them. This volume has always been considered a classical work in France. In 1847 he published a resumé of his great work on the geological relations of the coal basin of the Loire, which before it was completed occupied him nearly forty years. The complete work was only published in 1882, though it had long been in the hands of the government officers, and had been for years the authority for the miners of the district. Though much has been added to the methods of geological research since this work was finished, the new methods of investigation have only brought more prominently into view, how carefully all his observations were made, and how accurate his classification was.

During all this time he was actively engaged in the duties of his professorship and of his profession, and in preparing and publishing a large number of memoirs on geology in the *Transactions* of the Geological Society of France, the Geological Society of Lyons, and in the *Annales des Mines*, in addition to researches in various branches of the profession. As the natural result of his great services in the Department of the Loire he was, in 1852, made Director of the School of Miners at St. Étienne. Between 1852 and 1858 he published in the *Annales des Mines* the classification of the coals of the Loire and the Creuse. In 1855 he founded the Society of Mineral Industry of France, one of the most flourishing mining and metallurgical societies of Europe. He was its first President, and for a number of years continued to hold that office. When he resigned he was made Honorary President, which post of honor he retained until his death. He insured the success of the society, not only by presiding over its councils, but by contributing to its *Proceedings* some of its most valuable papers and discussions.

Some idea of the fertility of his genius, and also of his intense mental activity, can be had from an incomplete list of his metallurgical papers, which I have made from memoranda at hand. Many of these were the results of long and patient investigation, while others

were the productions of that quick and ripe judgment which made every one who knew him weigh well every word which fell from his lips. In 1855 he published a paper on "Masonry Blast Regulators for Blast-furnaces," and another on the "Calorific Power of Different Fuels;" one on "Methods of Exploitation adapted to Thick Beds of Coal;" one on "Some of the Silver Mines of Chili;" and a paper on "Tempering Steel." In 1856 he published a paper on "Bessemer Steel," and one on the "Lead Mines of Tuscany." In 1857, a paper on "Wet Processes for the Manufacture of Copper," and on the "Chemical Changes which Cast-iron undergoes while it is being made into Wrought iron." In 1860 he published one of the first investigations made upon the Bessemer steel process; in 1863, a "Memoir upon the Proper Shape of the In-walls of Shaft-furnaces;" in 1864, "On the Method of Agglomerating Fuels;" in 1867, a remarkable memoir on the "Manufacture of Steel;" in 1868, a complete resumé of the "Condition of the Metallurgy of Lead" at that time; in 1869, an elaborate examination of the "Heaton Process," a resumé of the then new "process for the manufacture of cast-iron;" and also some additional notes on the "Metallurgy of Lead;" in 1870, a note on the "Mechanical Properties of Steel containing Phosphorus;" in 1871, a memoir on the "Use of Quicklime in Blast-furnaces, and a Description of the Hoffman Furnace;" in 1872, his remarkable studies on the "Blast-furnace," and a memoir on the "Various Forms of Hot-Air Apparatus;" in 1873, a memoir on the "Calorific Power and the Classification of Coals," and a very remarkable paper on the "Heat Absorbed at High Temperatures by Cast-iron Slags and Steel;" in 1875, a memoir on the "Heat Absorbed at High Temperatures by Copper Mattes, Lead, and different kinds of Scoria in Fusion," and on the "Utilization of the Heat from Metallurgical Furnaces;" in 1876, as a result of the discussion in our own Society, a note on the "Real Meaning of the words, Iron and Steel;" in 1877, a paper on the "Forms and Interior Dimensions of Blast-furnaces," a continuation of his "General Researches on Blast-furnaces;" in 1879, a memoir on the "Incidental Products of Blast-furnaces;" in 1881, a paper on the "Kind of Steel most Suitable for Rails;" and also one on "Belgian Blast-furnaces." Just previous to his death he published a remarkable memoir on the relative "Oxidation of Irons, Cast-irons, and Steels." His last researches, published by his son after his death, were on the "Treatment of Copper in the Bessemer Apparatus." One of the most important of his papers is that on the "Action of

Carbonic Oxide," a memoir which was published by the Academy of Sciences with distinguished praise. No man in France was better qualified to have been a member of that body by learning, or by the additions made to the sum of human knowledge; but he, like some others among the greatest investigators of France, never was a member of the Institute of France.

In 1858 he was called to the Chair of Metallurgy in the School of Mines in Paris, which position he occupied with great zeal and distinction until the year 1872, when he was called to the position of Vice-President of the Council of Mines, the highest position in the Corps of which he was a member, the minister being the President. Just previous to leaving St. Étienne, at the direction of the French Government, and in connection with Mr. Lan, he made a report which was published in 1862 on the Present Condition of the Metallurgy of Iron and Steel in England, a book which was for some years classic, and which resulted in a number of important modifications in the industry of these materials in France. During all the time that he was professor, he was constantly engaged in making researches on the new methods of making steel, the dephosphorization of cast iron, steel and iron, and the use of gas at high temperatures, and on the metallurgy of lead, copper, and silver, besides many memoirs on general questions connected with metallurgy. He made the first researches and applications of the use of basic materials which eventually led to the discovery of the basic Bessemer process.

In 1876 Mr. Gruner was made a member of the International Committee appointed by this Institute to determine the nomenclature of iron and steel, and he wrote the best discussion of the whole subject which was submitted to the members of that committee. Through his influence and his discussion of the question in the technical societies and journals, that nomenclature was immediately received with great favor in France.

Immediately after resigning his professorship, he commenced the collection of his own researches in book form, and the publication at the same time of his lectures at the School of Mines in Paris, of which the first volume and half of the second only have been published. He was actively engaged in preparing the remaining volumes at the time of his death. It is not generally known that while he was preparing his lectures for publication, he was attacked by what he and all his friends believed to be a fatal malady, which kept him for many months confined to his bed, but did not, however,

interrupt the labor which he considered to be the great work of his life. Without much more time than I have at my command it would be impossible to render justice to the intense devotion to duty of this Christian man, lying as he supposed upon his death-bed, who still had the force of will and the moral courage to endeavor to finish the work which he had undertaken in the expectation of being of use to his fellow-men not only during his life, but also after his death. Some of those who were witnesses of this courage and fortitude have described to me the intense desire which this remarkable man had to do his duty in the state of life in which it had pleased God to call him, even in the very face of death. This same desire made him, while almost in the agonies of death, sign a letter to render a service to one of his old pupils, when his trembling hand could scarcely trace the signature.

In looking over his character as a whole, it is difficult to tell whether one should admire most his great learning, the wisdom with which he collected together the results of long practice in mines and works, and drew his conclusions from them, his constant devotion to duty, the quick and rapid intelligence with which he attacked every problem brought before him, the Christian modesty of the man, or the disinterested way in which he endeavored to make his own the interests of those with whom he was associated, or who applied to him for help.

GEOLOGICO-GEOGRAPHICAL DISTRIBUTION OF THE IRON ORES OF THE EASTERN UNITED STATES.

BY JOHN C. SMOCK, NEW BRUNSWICK, N. J.

WHILE I was engaged in the preparation of a catalogue or list of mineral localities of the United States, east of the one hundredth meridian, for the U. S. Geological Survey, the thought occurred to me that an arrangement or classification of the iron-ore districts of the eastern part of our country according to their geological horizons would be an interesting topic for a paper, and would furnish a basis upon which to arrange many facts brought out by the constant development of our iron-mining districts. Our text-books of mineralogy, geology, and ore-deposits describe the iron-ores and the

iron-ore districts in the order of species and not in that of geological age. The mineralogical classification has been followed almost exclusively. The magnetic iron-ores, the hematites, the fossiliferous ores and the limonites are the chief subdivisions in these systems of classification.

Prof. J. P. Lesley, in his *Iron Manufacturer's Guide*, 1859, based his arrangement upon, first, "the *primary ores*, the *brown hematite ores*, the *dyestone fossil ore*, the *carbonate ores*, and the *bog ores;*" and, second, the geologico-geographical distribution of these several forms or compounds of iron, occurring naturally and in sufficient abundance to justify their use as ores of iron. Prof. Henry D. Rogers, in his *Final Report on the Geology of Pennsylvania*, Vol. II., Part II., pp. 712–740, described briefly the ores occurring in the several geological horizons which appear in that State. The geological survey reports of other States, in their descriptions of rocks characteristic of the formations in them, include the iron-ores and note the modes of occurrence and extent of working. Generally the subdivisions of these official reports follow political boundaries, or the ores are described under the head of economic geology. In both plans of arrangement the geological horizon is made subordinate to the more popular or more practical, but less philosophical or scientific method of classification.

Taking the geological age or formation as the key to our arrangement, we discover the natural order. Geological structure underlies the surface features and determines the natural boundaries of districts; and the channels of production and trade follow in most cases the lines it indicates. The study of the origin of iron-ores is aided by this arrangement. Their general character and adaptation to manufacture also are to some extent revealed by the discovery of their geological position.

It has been often repeated that beds of iron-ore occur among the strata of all geological periods. That the oxides of iron and carbonates of iron are among the most common and most abundant of the chemical compounds which make up the earth's crust, is a well-known fact. They enter into the composition of all of our rocks; and there are formations of vast extent, whose strata in the aggregate contain inexhaustible quantities of iron. The red rocks of the Devonian age and of the Triassic age and the glauconitic sands of the Cretaceous and Tertiary ages are such formations. But there are gaps in our rock-series; and there are "barren measures" in which no workable extent of iron-ore is as yet known. Other

horizons are so rich in iron-ores that their very outcrops at once suggest the search after this mineral. And even in any given formation, belts marked by the occurrence of iron-ore, separated by broad intervals in which it is altogether wanting, are recognized. Hence the importance of a study of the marks whereby iron-ore deposits may be identified in new districts or localities. This irregular and often apparently confused alternation of ore-bearing belts or horizons and *barren strata* is suggestive in view of the genesis of these ores. Conditions favoring their deposition alternated with others of long duration when they were not laid down. As in the history of early man, there were *stone ages* and *iron ages*. In this relation it is important to lay aside the old and once prevailing theory that all metallic veins were erupted through the strata and were entirely foreign to them in origin and history. Nor is the theory of segregated veins of much interest or service. Our iron-ores, with few exceptions, are to be studied as other rocks. They make up a part of the series of stratified deposits, either as unaltered sediments or as metamorphosed beds, or they appear (though rarely) as unstratified masses. The theory of a sedimentary origin is more in harmony with the facts of deposition now in progress. Beds of iron-ore are now known to be forming on a large scale. Given the continuance of these favoring conditions, and the formation of beds of great extent is recognized as possible. And since the uniformitarian law is employed in discussing the origin of rock-strata, its application to the beds of iron-ore, which occur conformably stratified with them, is eminently scientific.

Laurentian.—Beginning at the base of the geological series with the Laurentian, immense beds of magnetitic iron-ore occur interstratified with the rocks of that period. As has been said by Le Conte, "it may well be called the age of iron." In the granitic and gneissic rocks of Maine there are beds of iron-ore on Buckfield and Marshall's Islands in Hancock County and on Mount Desert Islands, but they are not worked. The abandoned Franconia mine in Grafton County, New Hampshire, is on a *vein* of magnetite occurring with gneissic strata. Magnetite associated with hematite is found in granite at the celebrated Iron Mountain in Bartlett. The specular ore of Grafton, occurring in quartzite, is Archæan, but possibly Huronian. The magnetite and hematite of Hawley, Mass., where the country rock is talcose schist, may also be Huronian. The other localities in the State where this ore occurs in small quantities and in gneiss are, possibly, Huronian, or at least of the

Archæan age. The Connecticut localities of magnetite, mostly in Fairfield County, belong apparently to the Laurentian. None of them are of much importance as sources of ore. The celebrated Cumberland Iron Hill in Rhode Island is in a gneissic and granitic country-rock, and probably Laurentian.

Leaving New England, the debatable ground of geologists, we pass to the Middle States, where the Laurentian magnetites are immensely developed. The well-known Lake Champlain region is justly famous for its almost inexhaustible beds of magnetite. The production of this district in 1882 was estimated to be 675,000 tons. Its ores supply to a great extent the Hudson and Champlain valley furnaces. In the Highlands of the Hudson there is another Laurentian area, where magnetite occurs associated with gneissic rocks. There are several well-known mining centres in it. The annual product of this district may be estimated at 300,000 tons, making the total product of the Laurentian magnetic iron-ore districts of New York very nearly 1,000,000 tons a year. The same mountain range traverses the northern part of New Jersey and crosses the Delaware River into Pennsylvania. There are numerous mines in the former State, and their aggregate production in 1882 amounted to 800,000 tons. In the South Mountain, which is its name in Pennsylvania, there are several mines worked, besides many localities where ore is known to occur.

Magnetite has been mined in Maryland at Deer Creek, in Harford County, in what is supposed to be the Laurentian formation. Following the Blue Ridge southwest into Virginia, the Laurentian rocks contain some iron-ores; and mines were opened there at a very early period in the history of the State. The Ripplemead mine near Pearisburg in Giles County, the Gallaher bank near Abingdon in Washington County, the Wytheville mine, Wythe County, the Toncray mine, Bear Beds and Hylton mine in Floyd County, besides many other localities in these and in Carroll and Grayson counties, constitute a range of openings along the Blue Ridge.

North Carolina has several ranges of so-called "primary ores." The westernmost is on the Smoky Mountains or Unaka range, in the extreme northwest part of the State. The recently developed and immense beds of magnetite at Cranberry in Mitchell County are in it. On the east there is a range of magnetic ore in Burke, Caldwell, and Wilkes counties, which is reported as Laurentian by Prof. Kerr, the State geologist. Other ore-ranges of this period are the titaniferous magnetic ores from Greensboro to the Haw River in

occur in porphyry rocks. These immense deposits supply nearly all the iron manufacturing which centres at St. Louis. The product of this group of mines is about 300,000 tons annually.

The other western district is that of Marquette and the Menominee region in Michigan. Here magnetic and specular iron-ores, with limonites in some localities, occur in thick lenticular masses, lying between greenstones and quartzites. The production of these ranges in 1882 amounted to 3,543,313 gross tons. Of this amount 276,617 tons came from two mines south of the Menominee River and in Florence County, Wis. The rapid development of these iron-ore regions is one of the wonders in the history of mining. In the Penokie range in Wisconsin, from Lake Gogebic to Lake Numakagon, magnetites and manganiferous specular ores in quartzites are being developed. On account of their excellent quality they promise well.

West of Lake Superior, the Vermilion iron range in Minnesota is being opened to market by the construction of railways, and the deposits are said to be very promising. The ore is a hard, specular variety. Further to the north, on the Mesabic range, magnetite occurs with trap-rock and gabbro. Its associations, similar to that of the Penokie range in some respects, may be indicative of a like age. It is interesting as being the westernmost extension of the ores of this class in our Eastern and Central States.

This extraordinary development of the Huronian ores in the West and the large production of the Laurentian districts in the East are noteworthy. Specular ores mark the former; magnetites the latter. Comprehended by Archæan time, the great wealth of iron-ore in these two geological periods is another index of its great length, probably equal to the combined periods of all the succeeding geological ages. Of the total product of iron-ore for 1882 as estimated (from the statistics of iron manufacture) at 8,500,000 tons, at least 5,500,000 tons, or 65 per cent., came from the mines and mining districts of Laurentian and Huronian periods or of Archæan time.

Lower Silurian.—The classification of iron-ores according to their geological horizon is attended with uncertainty in the case of many localities and outcrops. And in no other is there more doubt and difficulty than in the Lower Silurian or Siluro-Cambrian horizon. The ores which belong in it are mostly brown hematites or limonites. They appear to be the result of alteration, by oxidation and hydration, of other compounds of iron; and in many places, apparently, this change has been subsequent to the upheaval and solidifi-

cation of the inclosing strata. It should also be stated that some of the deposits referred to the Lower Silurian may be of a much more recent age. The doubts respecting the true geological place of metamorphic strata assigned to the Lower Silurian affect the iron-ores in them also.

Returning to the northeast and pursuing a southwest and west-northwest course, as outlined by the rocks of the Archæan islands of the early continent, the only beds of iron-ore which we encounter in Maine that may be Lower Silurian are the extensive ones of red hematite, in calciferous slate in Aroostook County. In Vermont and New Hampshire there are no ores which are worked largely, unless it be the limonite of Bennington and Rutland counties. They are found in the metamorphosed or altered Lower Silurian limestones. The magnetic ore of Bernardston in Massachusetts has been referred to this horizon. It is of comparatively little economic importance.

The limonites of Berkshire County, Mass., of Litchfield County, Conn., and those of Columbia and Dutchess counties in New York, form a productive group, in which are the famous Salisbury and Amenia beds. They are found lying in somewhat irregularly-shaped deposits between. white limestone and talcose slate (Mather), and belong to the Lower Silurian. The existence of carbonate of iron in some of the deeper workings in these mines indicates that mineral as the source of the hematites which crop out and form the mass of the ore as opened. This district produced in the census-year about 220,000 tons of ore.

Going southwest the brown hematite deposits of the Great Valley from the Hudson to Alabama belong principally to the Lower Silurian. There are a few large mines in New Jersey which are worked at irregular intervals. In Pennsylvania the numerous ore-banks in the Kittatining valley from the Delaware to the Susquehanna; the mines west of the Susquehanna in York, Cumberland, and Franklin counties; the more widely-scattered deposits in the Kishcoquillas, Nittany, Sinking, Canoe, and Morrison Cove valleys of the central part of the State, are in it. Generally the ore occurs associated with magnesian limestone (Formation II. of Prof. Rogers). Situated as these ore-deposits are, near the anthracite coal-fields on the north and the semi-bituminous basins on the south, and yielding a large aggregate of excellent ore, they supply the Lehigh and the Schuylkill furnaces in part. No statistics of their production are accessible, but it is estimated that a large fraction of the Pennsylvania returns for iron-ore is from them.

The Maryland deposits of this geological horizon are worked in Washington and Frederick counties, but not largely.

In Virginia the Lower Silurian formations are rich in brown hematites, and numerous mines have been opened. Red hematite occurs in the lower slates of the Potsdam epoch, in Warren, Augusta, Rockbridge, Botetourt, Bedford, Wythe, and Smythe counties. Brown hematites are found in the same horizon at many points in the Great Valley and along the western foot of the Blue Ridge. They occur in the magnesian limestone also. These valley-ores are the basis of a growing iron-making industry.

The Great Valley crossing Tennessee is known as the Valley of East Tennessee. It abounds in iron-ore and constitutes the eastern iron-ore region of the State. The limonite is in banks or deposits in a matrix of clay, sand, chert, and débris of disintegrated rocks of the Knox group (Potsdam) and mostly in the Knox dolomite. Many localities in all the counties from the Virginia line to Georgia have been opened. Hematite in the Knox sandstone in Carter County, and at several localities in Sullivan County, is worked. It occurs in the Nashville series also (Trenton epoch), in Maury, Davidson, and Campbell counties, and is largely used at Chattanooga.

The extension of the valley into Alabama is there distinguished for its wealth in iron-ore, and in the Coosa valley ore-banks opened at the top of the dolomitic limestone at intervals from near Columbiana in Shelby County northeast to the Georgia line are supplying several furnaces; in the Cahaba valley from near Centreville in Bibb County to Gadsden in Etowah County; in Roup and Jones' valleys many mines opened in Bibb and Tuscaloosa counties; in Murfrees valley; in Willis valley, several mines; Brown's valley, no openings worked. Oolitic red hematite just below the Trenton limestone is traced from Pratt's Ferry, Bibb County, nearly to Birmingham. The importance of these ores in so close proximity to coals of the Cahaba and Coosa fields is rapidly becoming appreciated.

The only lower Silurian ores in North Carolina are in the southwest corner of the State, in Cherokee County; but they are too far from transportation lines to be valuable at present, and are not much opened.

In Georgia the Silurian formations, which crop out in the extreme northwestern counties of the State, are in places highly metamorphosed, and red hematites are found with some of these rocks. Brown hematites also are known, but these are not yet much worked.

In consequence of the great extent of the Lower Silurian outcrop in Missouri, there are many localities in the central and southeast districts of that State where hematites are mined. Red hematites occur in the second sandstone in Crawford, Phelps, and Dent counties, besides scattering banks in Franklin, Maries, Washington, Miller, Camden, Pulaski, and Shannon counties. Limonite is found in the southeast district in Saint Genevieve, Perry, and Cape Girardeau counties in small deposits. Richer and larger beds are known in Bollinger, Madison, Wayne, Iron, Butler, and Stoddard counties. They repose on the shales of the Upper Silurian and partly on the second magnesian limestone.

In Wisconsin, in the Potsdam sandstone, red hematite and limonite are mined at Westfield and at Ironton in Sauk County, and at Cazenovia in Richland County. They supply local furnaces.

As the Lower Silurian formations linked together and surrounded the Archæan rocks, their iron-ore localities are more widely scattered than those of the latter. The beds or ore deposits are distinguished for length of outcrop rather than thickness. And there are no such thick beds as in the Laurentian areas. Another point of difference is the absence of magnetite and specular ore and the prevalence of limonite. It is so distributed that it may be regarded as the characteristic iron-ore of this period. The total thickness of the ore-beds as compared with that of the rock is inconsiderable. Although they occur in sedimentary formations, the ores do not generally show any evidences of stratification, but are often irregularly-shaped bodies which apparently fill cavities and hollows in the inclosing rock-matrix, and doubtless some of them are of more recent formation than the rocks about them. Others are altered carbonates which are interstratified with the limestone or other sedimentary rock.

Upper Silurian.—The Upper Silurian age includes the Oneida, Medina, Clinton, Niagara, Onondaga, Lower Helderberg, and Oriskany groups of New York, and the Formations IV., V., and VI. of Prof. Rogers's Pennsylvania series. Shales, sandstones, and limestones are the prevailing rocks. Excepting the Clinton and the Oriskany (to a limited extent only), this age was not so favorable to the formation of iron-ore beds as the Lower Silurian. The Clinton, however, is characterized by its peculiar oolitic, red hematite, which follows its outcrops from New York almost uninterruptedly to Alabama. In the former State this ore, known also as *fossil ore*, is mined at Verona, Westmoreland, New Hartford, and Clinton in Oneida County; at Ontario in Wayne County, and in Madison County. These mines supply local furnaces only.

Following the Clinton southward into Pennsylvania, the largest mines on the fossil ore are near Bloomsburgh and Danville in Montour County, and Danville is the centre of its consumption. Thence it is traceable through Northumberland, Snyder, Mifflin, Centre, Juniata, Fulton, Huntingdon, and Bedford counties to the Maryland line.

In Virginia the Clinton is rich in ore; and mines are opened in it west of the Great Valley in Wythe, Giles, Bland, Tazewell, Russell, Scott, Lee, and Wise counties.

The fossil or "dyestone ore" of Tennessee occurs on the eastern border of the Cumberland table-land almost entirely across the State —160 miles—and to the Georgia line. The ore is largely employed in the Chattanooga iron district. In 1880 71,657 tons of it were mined.

The continuation of the dyestone ridges of Tennessee into Alabama exposes the ore interstratified with shales and sandstones on each side of the anticlinal Roup's and Jones's valleys and in what are known as Red Mountain ridges. It is extensively mined at several points southwest of Birmingham; also at Attala in Hills Valley, Gadsden, Round Mountain, and Gaylesville in the Coosa Valley.

Fossil ore is reported in Lookout Mountain, in Dade County, and Iron Ridge, Walker County, in Northwest Georgia.

In the Ohio Valley this formation carries ore in Eastern Kentucky and Western Virginia, and a few localities in Ohio. In Kentucky the Clinton ores are recognized in the Red River iron region, and there is an immense deposit in the Slate Furnace ore-bank in Bath County. Excepting this locality, it is not extensively worked.

In West Virginia the fossil ore is known to occur in Mercer, Monroe, Greenbrier, Pendleton, Hardy, and Grant counties; and in some of these localities large bodies have been opened.

The most important deposit of fossil ore in Ohio is at Sinking Springs in Adams County. It is known to exist at Todd's Ford, Clinton County, and near Zanesville, Muskingum County.

In Wisconsin there is an isolated distinctive outcrop of the fossil ore at Hubbard in Dodge County. The beds here are of unusually great thickness and are extensively worked.

Iron-ore from the Lower Helderberg formation and from the Oriskany group are mined in Pennsylvania in Huntingdon, Blair, and Perry counties. These ores are limonite. The Oriskany in the

Great Valley in Virginia has large deposits of brown hematite, particularly in Pulaski and Giles counties. Extensive beds in the Oriskany and Upper Helderberg formations are opened in Paint Lick Mountain, Rich Mountain, and Nye's Cove, in Tazewell County; in Clinch Mountain and Kent's Ridge in Russell County; in Powell's Mountain, Clinch Mountain, Fossil and Big Ridges, in Scott County; and at Bowling Green Forge in Lee County.

Some of the limonites in the central district of Missouri may be the equivalent of the Upper Silurian in age.

While the limonite and red hematite both occur in the Upper Silurian, the most persistent ore-species is the variety which is named from its geological horizon the Clinton or fossil ore.

Devonian.—The Devonian age in the eastern part of the country was marked by great accumulations of shales and sandstones. In the valley of the upper Mississippi there were limestones mainly, and there is a remarkable absence of iron-ores. Iron is present in most of the rocks, giving them their color and to the formation its name of *Old Red Sandstone.* A single locality of clay iron-ore is known in the Marcellus shale near Napanoch, Ulster County. In the Chemung group fossil ores are mined in the northern part of Pennsylvania in Bradford, Tioga, and Lycoming counties. In the Yellow Creek district in Blair County, and on the affluents of the Juniata in Juniata and Perry counties, the Marcellus shale carries ore (limonite). Carbonate ores are worked in Huntingdon, Bedford, and Fulton counties in the Devonian (Formation VIII. of Rogers).

Subcarboniferous.—In Pennsylvania in the shales and sandstones of Formations X. and XI. (Subcarboniferous), valuable beds of both limonite and carbonate ores are known. In the Mauch Chunk red shale carbonates occur at Scranton; at Ralston, Lycoming County; in Clearfield, Cambria, Huntingdon, Somerset, and Fayette counties.

One of the most productive districts of this age is the so-called Hanging Rock region of Kentucky and Ohio. The ores are both carbonates and limonites. In Kentucky they are mined in Greenup, Boyd, Carter, and Lawrence counties, and in the northeast part of the State, from the Ohio River south to the southern part of Carter County. North of the Ohio River and in the southeastern counties of Ohio, carbonates are mined in Washington, Jefferson, Holmes, Summit, and other counties. They are used in the manufacture of charcoal iron, chiefly made in this region, near the mines.

The Nolin River district in Kentucky also belongs to the Subcarboniferous horizon. The ores (carbonates, and limonites) are

known to occur in Edmondson, Grayson, Hart, Butler, and Muhlenberg counties, near the base of the Coal Measures, but they are largely undeveloped. In the Cumberland River iron region in the western part of the State limonite occurs in bodies of irregular shape on chert and in clay on the St. Louis or Subcarboniferous limestones. The deposits are of uncertain extent, but the aggregate of ore is immense and of excellent quality.

In West Virginia the Kanawha Valley is reported to have ores of this age, but as yet they are not much opened.

Small and unimportant occurrences of siderite (or carbonate of iron) and of limonite are known in Indiana, Illinois, and Iowa. In Missouri, limonite ore-banks in the Upper Osage district lie upon the Subcarboniferous.

In Arkansas, siderite is reported in Franklin, Pope, Washington, and Madison counties—all in the Subcarboniferous.

Carboniferous.—The ores of the Carboniferous age, like those of the preceding, Subcarboniferous, are mainly carbonate and limonite. The former are probably the original and unaltered beds, while the latter appear to be altered outcrops. Generally the beds are somewhat concretionary in structure and thin, and interstratified with shaly strata. The more earthy variety of the carbonate is known as clay-iron-stone. The Carboniferous iron-ores are confined mainly to Pennsylvania, Ohio, West Virginia, and Kentucky. In Pennsylvania the carbonate ore occurs in all the coal-basins. Brown hematites abound also and particularly along the outcrop of the "ferriferous limestone." They are in the western part of Indiana County, in Northern Armstrong, in Clarion, Jefferson, Butler, Lawrence, and Beaver counties, and in large beds. Other localities which are worked are in Centre, Clearfield, and the coal measures territory of the southwestern part of the State. No mines are worked in the anthracite coal basins of the State. Black-band ore occurs in the coal measures at Pottsville and in the Snowshoe basin in Centre County.

In Maryland siderite is reported in two or three localities, in the western part of the State, in Alleghany County.

In West Virginia there are workable beds of clay-iron-stone in the lower coal measures and lower barren measures at many localities, some of which are worked. Black-band ore occurs also in Wayne, Kanawha, Fayette, Nicholas, and Clay counties.

Next to Pennsylvania, the iron-ores of Ohio which occur in this horizon are most extensively developed. The ores are limonite and

clay-iron-stone. They are opened in the eastern part of that State and in the Hocking Valley, between Monday Creek and Hocking River in Perry County; at Bessemer in Athens County; also in Muskingum, Hocking, Vinton, Jackson, Scioto, and Lawrence counties. The black-band ore is mined in the Tuscarawas Valley and in Stark and Tuscarawas counties.

The Hanging Rock region of Eastern Kentucky has some ores in the lower coal measures, both carbonates and limonites and interstratified with the coal measures.

In Southern Indiana clay-iron-stone occurs in thin beds, but none of them are worked, although in close proximity to the celebrated block-coal mines.

Thin seams of carbonate of iron are found in the coal measures of Illinois, in Hardin, Schuyler, Crawford, Edwards, and Wayne counties. In Missouri, in the southwestern part of the State, brown hematite occurs in the coal measures. Other localities in the same horizon, but of carbonate ores, are found in the central and north central districts. In Kansas spathic ores are reported near Fort Scott; on the Neosho; and in the Marais des Cygnes coal measures.

The type-ore of the Carboniferous may be said to be siderite, or clay-iron-stone, varying by oxidation and weathering to limonite, or, by an accession of carbonaceous or coaly matter, to black-band ore. In themselves these ores are neither so rich nor of so good quality as the ores of older geological formations. And often the beds are thin, and in mining them much rock also must be raised. But they are so near to the fuel that they can be used with profit, and hence are the basis of the iron manufacturing of several districts in the Ohio Valley.

Triassic.—The Triassic rocks are noted for the amount of iron oxide distributed through the mass of their strata. But with the single exception of the black-band ore at Egypt in North Carolina, in the coal and shale series of the Deep River belt, no mines are opened in them.

Cretaceous, Tertiary, Recent.—The Cretaceous and Tertiary formations contain numerous deposits of bog-ores and limonites, but some of them may belong to the Recent period, particularly the bog-ores. In Eastern Maryland there are large beds which were formerly worked; in the counties bordering the Susquehanna limonite beds occur with the clays of Cretaceous age. In Delaware, in New Castle County, there are extensive deposits which are worked for local furnace-supply. Throughout the Atlantic coast belt the deposits of

ore which may be of the Tertiary age are numerous but of little economic importance. The Western iron region of Tennessee is perhaps the most remarkable of these more recent groups of iron-ore, as it forms a belt fifty miles wide crossing the western counties of the State and its ores are of excellent quality and are continuously mined at a number of localities. They occur in irregular lumps and hollow concretions in a sandy matrix (the "ore-region gravel" of Safford). The localities of bog-ore of Recent age are common almost everywhere, throughout the Atlantic coast border and in the Gulf States. These ores are in process of accumulation and deposition to-day.

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*CONTRIBUTIONS TO THE GEOLOGY OF ALABAMA.**

BY E. J. SCHMITZ, NEW YORK CITY.

THE following abstract of an unpublished treatise, prepared by me, on the geological formations and minerals of the State of Alabama, is deemed of interest to the Institute.

This State, called after the river of the same name (which, formed by the junction of the Coosa and the Tallapoosa, waters, with its tributaries, more than half the State), is divided by its main watershed into a larger southern district, sloping south and southwest, and drained into the Gulf of Mexico, and a smaller northern district, sloping generally north and west, and drained into the Tennessee. Geologically the State may be divided (according to historical geology) according to the different formations it exhibits, among which I include the Azoic, the existence of which in Alabama has been doubted by some; or it may be divided (according to structural geology, as closely related to topography) into a north and northwestern, a middle, and a southern zone.

I. THE NORTHWESTERN ZONE.

This may be divided into the Tennessee Valley, forty to fifty

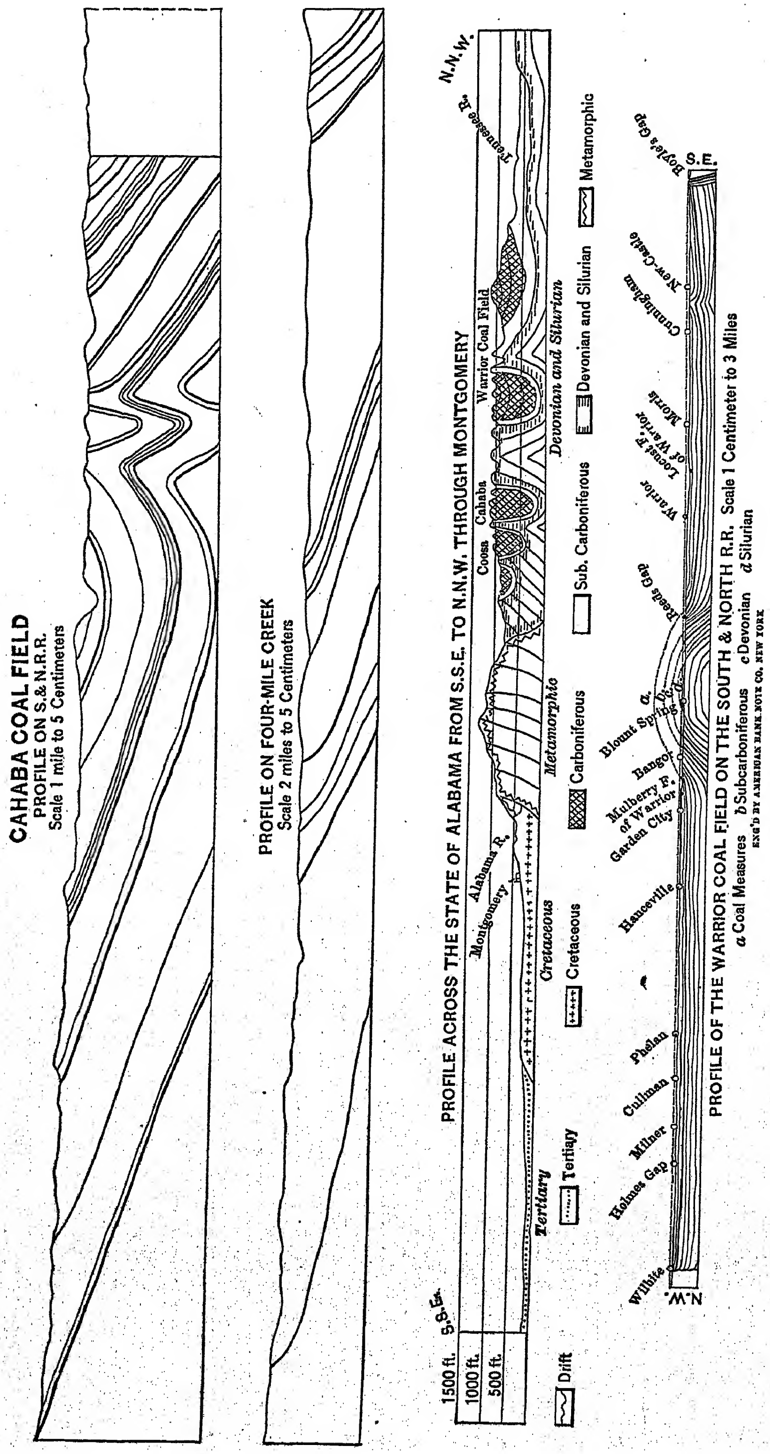
* This paper was presented at the Roanoke Meeting by Dr. R. W. Raymond, and was read by title under his name, he having undertaken to prepare it for publication from the material furnished by Mr. Schmitz. But Mr. Schmitz having been elected a member at the Roanoke Meeting, it seems better to print the paper now as coming directly from him.

miles broad, and the northern part of the Warrior coal-field with the so-called Raccoon and Sand Mountain, a connecting link with the Cumberland coal-field in Tennessee. The Tennessee Valley exhibits the Subcarboniferous rocks. I will not here reproduce at length the detailed account of it contained in my longer treatises. Of the brown hematites found in the siliceous group of its rocks I give some analyses in the tables below. The deposits have often a thickness of over 30, and even up to 60 and 70 feet. Near West Point, in Lawrence County, in Southern Tennessee, I observed deposits of the last-named thickness. The valley contains numerous caves and springs. Kaoline occurs near Huntsville; ferrocalcite east of Wilhite Station, in Cullman County, and mineral tar (asphaltum) and ozocerite (the former between decomposed sandstones, and the latter included in the former) have been noticed by me west of Falkville Station, in Morgan County. The so-called "tar-spring," in Lawrence County, discharges with its water, during the summer months, a mineral tar, which seems to be probably the product of the oxidation of petroleum. The occurrence of this discharge in the summer only appears to be the result of the temperature, which renders the substance fluid. But, passing lightly over these topics at present, we come to the more important one of the coal-formation, which it will be convenient to treat wholly under the head of

II. The Middle Zone.

The Alabama coal-fields are undoubtedly an extension of the great Appalachian coal-field. The position of the beds, nearly horizontal in the northwestern part, and highly tilted in the more easterly sections, while the rocks still further east, outside the coal, stand nearly vertical, corroborates the accepted view of the formation of the Appalachian chain by pressure from the southeast and from below, along the Atlantic coast. The condition of the rocks also indicates the strongest disturbing and altering forces to have operated from the eastward. The faults in that section are much deeper, going down to the Silurian rocks, while in the westerly section they extend only to the Subcarboniferous.

Going from east to west we have the following valleys determined generally by faults and anticlinals: The Coosa valley, dividing the metamorphic region from the coal-field of Lookout Mountain and the Coosa coal-field; Cahaba valley, dividing the Coosa from the Cahaba coal-field; Jones', Roup's, or Will's valley, dividing the Cahaba from the Warrior coal-field in the southwest, and the


CAHABA COAL FIELD
PROFILE ON S.& N.R.R.
Scale 1 mile to 5 Centimeters
PROFILE ON FOUR-MILE CREEK
Scale 2 miles to 5 Centimeters
PROFILE ACROSS THE STATE OF ALABAMA FROM S.S.E. TO N.N.W. THROUGH MONTGOMERY
S.S.E.
N.N.W.
1500 ft.
1000 ft.
500 ft.
Montgomery
Alabama R.
Coosa
Cahaba
Warrior Coal Field
Tennessee R.
Tertiary
Cretaceous
Metamorphic
Devonian and Silurian
Drift
Tertiary
Cretaceous
Carboniferous
Sub. Carboniferous
Devonian and Silurian
Metamorphic
PROFILE OF THE WARRIOR COAL FIELD ON THE SOUTH & NORTH R.R. Scale 1 Centimeter to 3 Miles
a Coal Measures b Subcarboniferous c Devonian d Silurian
ENG'D BY AMERICAN BANK NOTE CO. NEW YORK
N.W.
S.E.
Wilbite
Holmes Gap
Milner
Cullman
Phelan
Hanceville
Garden City
Mulberry F. of Warrior
Bangor
Blount Springs
Reeds Gap
Warrior
Locust F. of Warrior
Morris
Cunningham
New-Castle
Boyle's Gap

Lookout mountain from Sand and Raccoon Mountains in the northeast; Murfrees' valley, dividing parts of the Warrior coal-field from Sand Mountain; and Tennessee valley (the northeastern part), dividing parts of the Cumberland coal-field extending into Alabama from Raccoon Mountain. This gives us from west to east the following division of the Alabama coal-fields: (1) spurs of the Cumberland; (2) the Warrior; (3) the Raccoon and Sand mountains; (4) the Lookout Mountain; (5) the Cahaba; and (6) the Coosa coal-fields.

The first, third, and fourth of these may be dismissed with a few words. The spurs of the Cumberland Mountain in Alabama may contain in parts one or two workable coal-seams of from two to four feet in about 500 feet of coal-measures. Portions of the Raccoon and Sand mountains may contain, in 600 to 700 feet of coal-measures, two or three workable seams from two to four feet thick. In the southern end of Sand mountain, between Jones' valley and Murfrees' valley, I think the same veins occur as I found in that part of the Warrior field west of Murfrees' valley. I noticed here (in St. Clair County) a vein five feet thick having the characteristics of the Upper Newcastle vein of the Warrior field. The Lookout Mountain in Alabama contains, so far as known, in 600 to 700 feet of coal-measures, only one workable vein, two and a half to three feet thick. This has been opened in De Kalb County.

The Warrior Coal-field.—This has the form of an equilateral triangle, and is divided into a plateau or highland (which forms the northern and northeastern region of the field), and the basin proper. The northern or northeastern part is again divided by Brown's valley into a northern and a southern division. The basin proper extends more to the southwest.

The whole area of the Warrior field is about 5000 square miles, extending over the whole or parts of Marshall, Blount, Cullman, Winston, Morgan, Lawrence, Franklin, Marion, Walker, Fayette, Jefferson, and Tuscaloosa counties. The northern division of the plateau of the Warrior field extends over parts of Morgan, Marshall, Cullman, Blount, and Winston counties; the southern over parts of Blount, Marshall, and Jefferson.

In the northern part of the plateau no workable coal-bed has yet been discovered. A vein of about 2 feet is exposed in Morgan County, under a high bluff on the mountain side, rising 700 to 800 feet above the limestone valley; but this vein seems not to extend further south. The coal-measures represent here 500 to 600 feet. Towards

the southwestern extremity of this division the measures increase in thickness and show two workable veins of about 2½ feet. The area of this division is about 750 square miles. The southern division of the highland covers about 250 square miles, and contains three or four workable beds, with a thickness varying from 2½ to 3½ feet in about 700 to 900 feet coal-measures.

The basin proper, which includes the southwestern and the greater part of the western field, contains about 4000 square miles. That part of the basin proper which is the extension of the southern division of the plateau contains, so far as known, on an area of about 150 square miles, in about 1000 feet of coal-measures, four or five workable veins, in thickness from 2½ to 4 feet. Further south, west, and northwest, in Jefferson County, and not far from the Southern and Northern Alabama Railroad, the coal measures increase to about 1800 to 2000 feet, and the workable veins of coal to nine in number. The most important vein among these shows a thickness of from 4 feet 8 inches to 6 feet, and has only one shale-parting, with about four feet of coal in the upper bench. This seam is the so-called Brown, Pratt, or Coketon seam, and is now worked by three different companies—the Pratt, the Milner, and the Woodward Furnace companies.

The extension of the Pratt vein has not yet been ascertained. There exist different opinions about the identity of similar coal veins occurring in other localities in the basin. My opinion is that so far as now can be seen, the Pratt vein underlies an area of about 150 to 175 square miles; but I have no doubt that by closer examination in the southern portion of the basin this area may be shown to be greater.

The following approximate sections of the basin, west of Birmingham, will show the relations of the field. I have numbered the workable veins.

General Section of the Warrior Coal-field about Ten Miles West of Birmingham.

		FEET.	INCHES
1. Soil, drift, and coal-measures, containing some small seams of coal,		350	
2. Coal (Pratt, Coketon, or Brown's seam), No. I.,	4 ft. 8 in. to	6	
3. Interval,	20 ft. to	22	
4. Coal, small seam,	1 ft. 4 in. to	1	6
5. Interval,		28	6
6. Coal, in two benches, {2 feet coal, 2 feet clay, 2 feet coal,} No. II.,		6	

No.				FEET.	INCHES
7.	Interval, containing some small seams of coal,	180 ft.	to	220	
8.	Coal-seam, No. III.,	2½ ft.	to	3	
9.	Interval,	180 ft.	to	190	
10.	Coal-seam, No. IV.,	2½ ft.	to	3	
11.	Interval,			25	
12.	Coal-seams, Newcastle, { Newcastle upper vein (slaty),	4½ ft.	to	6	
	Interval,	10 ft.	to	13	
	Newcastle, lower vein (little better),			4	6
13.	Interval,			20	
14.	Coal, small vein,			1	10
15.	Blackband,			1	6
16	Coal, dirty seam, in some places workable, { Coal = 1 ft. 5 in., Slate = 8 in., Coal = 1 ft. 5 in., } at Newcastle = 3 ft. 6 in.; near Warrior Station = 4 ft. 8 in., No. V., 3 ft. 6 in.,		to	4	8
17.	Interval,			25	
18.	Conglomerate,	15 ft.	to	20	
19.	Coal,			1	6
20.	Interval,			81	10
21.	Coal, good,			1	6
22	Interval,			40	
23.	Coal, Jefferson vein (two benches), No. VI.,	3 ft. 3 in.	to	4	
24.	Interval,	28 ft.	to	30	
25.	Coal, very good, Black Creek vein, No. VII.,			2	9
26.	Interval,	40 ft.	to	80	
27.	Cannel coal and blackband. It exists only over a small area,			2	4
28.	Interval,	½ ft.	to	4	
29.	Coal, good, Warrior vein (2 benches), No. VIII.,	2 ft. 9 in.	to	3	6
30.	Interval,			20	5
31.	Coal,			1	8
32.	Interval,			7	6
33.	Coal,			2	2
34.	Interval,			295	6
35.	Coal, hard,			1	6
36.	Interval,			17	
37.	Coal,			1	4
38.	Interval,			12	
39.	Coal, good, No. IX.?			2	6
40.	Interval to the Conglomerate, containing some small veins,	250 ft.	to	300	
41.	Conglomerate,	100 ft.	to	150	
	Total,			1800 to 2000 ft.	

The data for the above are the different profiles or sections, which I have partly measured myself, and the boring results in different locations of the field (published in Professor Smith's Reports).

It will be seen that the nine workable veins of this section contain in the aggregate about 30 feet of coal, which would be increased to about 40 feet if the coal of the Newcastle vein could be cleared from slate. If the Newcastle veins are, as they seem to be, identical with some of the larger veins of Walker County, they have changed in character, since the Walker County veins show purer coal, but contain, nevertheless, a number of slate-partings, which leave, as far as my knowledge goes, nowhere more than 3½ to 4 feet of coal in one bench.

As a maximum, in any coal-vein which could be observed, I found about 5½ to 6 feet of good coal, and in one bench about 4½ feet.

Some veins known in the southern division of the basin show a thickness of 5 to 6 feet in Tuscaloosa County, and are considered to overlie the Pratt vein; but this opinion is not yet sufficiently proved.

The above approximate section of the Warrior basin, west of Birmingham, differs from the general profile of Professor Smith, State Geologist of Alabama, in the following points (see his Report of 1881):

1. While Professor Smith gives about 900 feet between the Pratt vein and the Newcastle vein, my section gives only 460 to 470 feet.

2. The interval between the Black Creek vein and the Warrior vein is, in Professor Smith's profile, given as from 270 to 280 feet, and in my profile as from 40 to 80 feet. I obtained this distance by measurement of the dip of the coal-measures north of the Locust fork of the Warrior near Warrior Station (where the Black Creek vein and the Warrior vein crop out within a distance of half a mile), and measurement of the elevation with an aneroid barometer (which always proved very accurate). I may remark here that the Warrior vein shows at Warrior Station, at Pierce's northern mines, and at Hoehne's mine, 2 feet 4 inches of blackband-ore 4 feet above the vein; but only a quarter-mile further south, at Pierce's southern mines, the blackband is but a few inches thick, and lies right on top of the vein. This justifies the opinion that the ore soon gives out entirely, which would correspond with the fact that the Warrior vein, "with the characteristic blackband-ore," could be found at no other locality of the coal-field except near Warrior Station.*

* The position of the Warrior vein relatively to the Black Creek vein has always been uncertain, as the Warrior vein is known only near Warrior Station, and no section is known to me which shows the two veins. The boring near Morris Station, a few miles south of Warrior Station, did not strike the Warrior vein,

3. By the above-named differences between Professor Smith's section and my own, in regard to the measures between the Pratt vein and the Newcastle veins, on the one hand, and the Black Creek and the Warrior, on the other hand, the thickness of the coal-measures from the Pratt vein down is made to differ, being about 2500 feet in Professor Smith's report and about 1500 to 1700 feet in my section.

4. We differ as to the number and thickness of the veins between the Pratt vein and the Newcastle veins.

5. Professor Smith gives only one vein of 5 to 6 feet at Newcastle (Newcastle vein), while there exist two, an upper vein of 4½ to 6 feet, and a lower vein of 4½ feet, with an interval of 10 to 13 feet. This corresponds with the so-called Calvary Williams vein, on Village Creek, which is thought to be identical with the Newcastle veins.

Of the above-mentioned coal-veins, the following have been tried for coking purposes, and have proved to give good coking coals, viz.: The Pratt, Black Creek, and Warrior veins, and also the coal from the Newcastle upper vein (after washing). Thus, of the five veins worked in the Warrior field, the coal of four has been tested and found suitable for coke. I give here the analyses of the cokes from two of these different veins, and annex some analyses of cokes from other bituminous coals from the Cahaba field and from other States:

No.		County.	Analyst	Moisture and Vol. M.	Fixed Carbon.	Sulphur.	Ash.
1	Coke from Pratt vein	Jefferson	Oxm.F.	...	86.110	...	13.440
2	Coke from Pratt vein	"	"	...	89 110	...	10 890
3	Coke from Pratt vein	"	"	.	87 000	...	13.000
4	Coke from Pratt vein	"	"	0 530	88 730	0 810	9.930
5	Coke from Pratt vein	"	"	0 600	85 800	1.080	13.396
6	Coke from Pratt vein	"	"	0.160	93.010	0 575	6.830
7	Coke from Newcastle upper vein (washed)	"	Gesner.	0.280	85.430	0.160	14.130
8	Coke from Ætna vein (Tennessee)	...	"	0.670	82.310	0.840	16 180
9	Coke from black shale vein (Cahaba)	Jefferson	Hough.	4.290	89.910	...	6.530
10	Coke from Helena vein (Cahaba)	"	"	1 200	81 900	0.535	16.250
11	Coke from Connelsville (Pennsylvania)	...	.. ...	0.420	86 410	0.270	12.870
12	Coke from Elkhorn Creek	Pike.	.. .	0.060	94 340	0.788	5.600

notwithstanding the hole extends more than 100 feet below the Black Creek vein. I have much evidence to show that the Warrior vein, near Warrior Station, cannot be so far as that below the Black Creek vein. There are only two possibilities,—either the Warrior vein gives out further south, or the Warrior vein and the Black Creek vein are identical. I give in my section the interval between the two veins, according to my measurements and calculations, having to accept one of these alternatives.

In analyses Nos. 5, 6, and 10 of the above table, the constituents of the ash are determined as follows:

No	Silica.	Alumina.	Iron Oxide.	Lime.	Magnesia.	Potassa.	Soda.	Phosph. Acid.	Total.
5	6 700	3.596	2 590	0 260	0 150	trace.	trace	0 100	13.396
6	3 000	1 870	1 530	.			. .	..	6 400
10	9.330	4 660	1 610	0.400	0 250	trace	trace	. .	16.250

The ash of No. 12 is reported to be brownish-red.

As to the constitution of the coal of the Warrior field, I have compared a considerable number of analyses made for private owners, or published in Professor Smith's report, and find the principal elements to range as follows in percentage:

	Sulphur.	Moisture.	Volatile Combustible	Fixed Carbon.	Ash.
From . .	0 36	0.27	15.29	44.52	1 90
To . . .	3.07	7.28	38.08	79 22	26.36
Average . .	0.65	2.25	31.25	58.50	7.50

It should be remarked that most of these samples came from outcrops, and that the averages are not what might be expected from fairer samples.

Concerning the blackband-ore, found in the Warrior coal-field, one vein above the Warrior vein, north of Warrior station, and the other at Newcastle, I remark that the former contains only about 21 per cent. metallic iron and 40 per cent. of bituminous coal, while the latter contains 35 per cent. of iron, and when roasted 55 per cent. Both ores have been roasted and used in the blast-furnace, the ore from the Warrior vein with but very little success. This ore contains so much bituminous coal that it was found difficult to regulate the temperature necessary for the roasting process. The heat produced was mostly so high that a partial melting and sintering was the result, which produced large and heavy lumps not fit for use in the furnace. This blackband-ore, it is said, should be mixed with brown ores, which have to be roasted, to keep the temperature down, and, on the other hand, save the fuel otherwise necessary for the brown ore.

The Cahaba Coal-field.—This field is separated from the Warrior field by the long valley called Jones', Roup's, and Will's valley, and extends from northeast to southwest for about 50 miles, with a width of 3 to 10 miles, the widest part being in the southwest. It covers

about 250 square miles, including parts of St. Clair, Jefferson, Shelby, and Bibb counties. The Cahaba coal-field has a monoclinal formation, with a considerable dip to the southeast. In the southwestern part of the field, as well as in the southeastern part, this dip increases from the western side towards the eastern, so that while the dip shows along the western edge of the field not more than 5° to 10°, it has increased on the eastern edge to from 40° to vertical. In the middle portion of the field, where the S. and N. R.R. crosses it, the measures are folded and crushed. Along the southern edge of the field we pass immediately from the coal-measures to the Lower Silurian rocks, which also dip in the same direction. This is the great fault first mentioned by Mr. R. P. Rothwell. The Cahaba coal-field shows two well-defined series,—one in the southwestern field, near Montevallo, and the other about 20 miles further northeast. The upper series is called by Rothwell the Montevallo series, contains four beds from 2 to 4 feet thick, and spreads over about one-third of the entire field. The lower series shows, according to Rothwell, near Four Mile Creek, which is in the southwestern part of the field, eight veins from 2 to 8 feet thick. Further northeast, on the line of the S. and N. R.R., which traverses the field, the lower or Cahaba River group contains about fourteen veins, with seven workable veins, in about 2000 feet of coal-measures. Of the non-workable veins it may be, however, that some may prove to be identical, which would reduce the number of veins.

The following are the workable veins on the S. and N. R.R. in the order of superposition:

		FEET.	INCHES.
1. Helena seam,		4	0
2. Conglomerate seam,	3 feet to	3	6
3. Black shale or McGinnis seam,		2	6
4. Buck seam,		3	6
5. Shute seam (with one parting),	3 feet 6 inches to	4	0
6. Cahawba seam or Wadsworth seam (?),		3	0
7. Gould seam,		3	6
Aggregate thickness,		23 to 24 feet.	

While the veins in the middle part of the field, where the S. and N. R.R. crosses, are crushed together and show a minimum thickness with not over 4 feet of coal, we see in the southern part of the field the veins increasing. Also further northeast from the S. and N. R.R. we find in the northeastern part of the field the veins thicker than in the middle part; and about 25 miles northeast from

the S. and N. R.R. six or seven workable veins are shown, with a thickness of from 2½ to 12 feet, showing, however, in the Big (12 feet) vein not more than 5½ to 6 feet of clear coal. The productive coal-measures here may represent a thickness of 2000 to 2500 feet. An identification of the different veins in the different parts of the field has not yet been attained.

I will call attention here to the probability of tracing veins from the Warrior over into the Cahaba field. I have traced a vein, very similar to the upper Newcastle vein, from the opposite side of the southern part of the plateau of the Warrior field (between Brown and Murfrees' valleys) over to the southern extremity of the Sand Mountain coal-field, between Jones', Roup's, and Will's valley and Murfrees' valley. This vein has all the characteristics of the upper Newcastle vein. As the different coal-fields in Alabama before the formation of the anticlinals must have formed one undivided field, it should be possible to connect the veins of the now divided fields. The Newcastle veins, which have been formed in the Warrior field over an area more than 50 miles in length, seem to be particularly adapted to this purpose. Later investigations and study of the northwestern part of ,the Cahaba coal-field may probably connect the big (12 feet) seam in the Cahaba with the Newcastle veins.

From a number of analyses of coal from the Cahaba field, selected by myself and collected from private examinations and Mr. Rothwell's table, I find: Sulphur, from 0.08 to 2.80 per cent., with an average of 0.55 per cent.; moisture, from 0.30 to 2.55 per cent., with an average of 1.85 per cent.; volatile combustible matter, from 27.04 to 37.50 per cent., with an average of 32.00 per cent.; fixed carbon, from 57.23 to 66.58 per cent., with an average of 62.00 per cent.; ash, from 1.09 to 9.12 per cent., with an average of 3.25 per cent. By comparing the average figures from the Warrior and the Cahaba, we find that the latter is the purer coal. Three or four of the coals from the Cahaba coal-field have been tried with success for coking purposes; others are dry-burning coal.

As the measures of the Cahaba coal-field mostly dip at large angles (the dip in the southwestern part of the field is from 5° to 10° on the western side, increasing towards the eastern side to from 40° to nearly vertical, and in the middle and northern part also changes from 5° to vertical), mining in the Cahaba coal-field is more difficult, and cannot be done above water-level with natural drainage, as is the case with a good deal of the coal in the Warrior

field. But the area in the Warrior field which could be worked above water-level is not as large as I have found it in other parts of the Great Appalachian coal-field, as, for instance, in the Cumberland field in Virginia and Kentucky. In about one-third of the area of the Warrior coal-field, where workable veins are known, some of the veins can be worked above water-level.

The Coosa Coal-field.—This lies east of the Cahaba field, along which it extends from northeast to southwest for about 40 miles, and includes parts of St. Clair and Shelby counties. This part of the coal-formation west of the Cahaba field shows on the geological map of Alabama a width of 6 to 10 miles, parted by an anticlinal into two parts for nearly its entire length; but it seems that only the eastern part bears the name of Coosa Coal-field, as Prof. Smith gives the area of this field as only 100 square miles, while the whole area of this coal-formation is about twice as large. Very little has been done in developing this field. Three or four workable veins are known, which show a thickness of from 2½ to 4 feet.

The Silurian Valleys.—I have mentioned above the different Silurian valleys, which lie between the different coal-fields. The Coosa valley, which is the largest and most easterly division of the Silurian formation, is a continuation of the great Appalachian valley extending from Pennsylvania downwards to Alabama. This valley makes connection westwards, around Coosa and Cahaba coal-fields with the Cahaba valley, Jones', Roup's and Will's valley (of which latter Murfrees' valley may be called a northeastern extension), and is very rich in brown hematite or limonite ore. The Coosa valley proper is a monoclinal valley, and is formed mostly by the lower Silurian rocks, chiefly the Acadian, Potsdam, Quebec, and Chazy groups (Dana), while the Upper Silurian rocks are only found in little spots (as for instance the Clinton, near Columbiana). In the other Silurian valleys, Cahaba valley, Jones', Roup's and Will's valley, and Murfrees' valley, which are anticlinal valleys, both the Upper and Lower Silurian rocks are found together; but still the older rocks predominate. The Quebec group in these valleys is the bearer of very valuable brown hematite deposits of great extent, sometimes hidden in clay, sometimes laid bare along the ridges or found in hard quartzose rock. These deposits of brown ore show sometimes a thickness or depth of 20, 30, 40 and more feet, and are mined in the Coosa valley in Talladega, Shelby, Bibb and other counties. As I have mentioned above, the Upper Silurian rocks are found in Coosa valley in little spots only. A small area of the Clinton group, con-

taining the Clinton or Red ore, is known near Columbiana, Shelby County.

On the western side of Coosa valley the Lower Silurian rocks are brought in contact with the Coal-measures, which in the southern part are brought to the same level, making a fault of about 10,000 feet, as Mr. Rothwell first pointed out. Further north along the fault, the Acadian and Potsdam rocks can be seen next to the Coal-measures at many points. Southeast of this fault, we find the Quebec group nearly through the entire valley. About in the middle of the valley, and near the Selma, Rome and Dalton R.R., is a group of hills and mountain knobs, forming a broken line running from northeast to southwest. These hills are formed of rock older than the Quebec group—partly Calciferous, but mostly Potsdam sandstone. They represent a small fault in the formation of the valley.

The rocks of the Coosa valley dip mostly to the S. E. at high angles. The valley extends from Georgia into Shelby County, and makes connection around the Coosa and Cahaba coal-fields with the Cahaba valley in Bibb County. It covers the following counties or parts of counties: Cherokee, Etowah, St. Clair, Calhoun, Talladega, Shelby and Bibb, and extends from the Georgia line in a southwestern direction for about 80 to 90 miles in length and about 30 to 40 miles in width.

The Cahaba valley is only a few miles broad, and is an anticlinal valley. But on the eastern side of the valley there exists a fault similar to that in the Coosa valley, which brings the lower Silurian up to the surface and in contact with the Subcarboniferous rocks. Fragments of the Clinton group are occasionally found here. The rocks of the Quebec group mostly form the floor of the valley, and contain here also deposits of brown hematite-ore of great extent. On the east side of the Cahaba valley we pass successively, going eastward and geologically upward, the Quebec, Chazy, Trenton, fragments of the Clinton, fragments of Devonian (black shale) and the Subcarboniferous limestone, which rocks however do not show the thickness which has been noticed further north in Pennsylvania, etc.

The Jones', Roup's and Will's valley is the long valley dividing in its lower part the Cahaba from the Warrior field, and in its northern part the Cahaba and Lookout Mountain field from the so-called land mountain. This valley is from 6 to 10 miles wide, and extends from the Georgia State line southwestwards into Tuscaloosa and Bibb county, Alabama, having a length of about 120 miles. The Jones', Roup's and Will's valley is also an anticlinal valley, in which

the rocks of the Quebec group form the floor, while we find, going to both edges, successively the higher Silurian rocks, Quebec, Chazy, Trenton, Clinton, the Devonian, the Devon black shale, and the Subcarboniferous limestone, followed by the Coal-measures. It is characteristic for this and the Murfrees' valley, that we find on both sides of the valley the Clinton or Red mountain group, containing the red fossiliferous ore, while in the middle of the valley between the Red mountains the brown hematite-ore is found in the older rocks. In the southwestern part of the valley, we find the strata all dipping towards the southeast; therefore the rocks of the anticlinal must have been turned over to the west, producing a sharp fold. In the northern part of the valley we find the regular anticlinal formation, the older rocks dipping on both sides under the Coal-measures. In the lower Murfrees' valley, however, we find again such a folding and pushing of the strata to one side, but here to the southern side of the valley, causing the rocks to dip towards the northwest.

The Clinton group, bearing the Clinton or fossiliferous ore, occurs, by reason of the anticlinal formation noticed through the entire valley in two different exposures or Red mountains, a western and an eastern. The eastern Red Mountain is the most important, as showing a greater thickness of the red ore, and can be seen the entire length of the valley, along the western edge of the Cahaba coal-field, sometimes 100 feet above the floor of the valley, sometimes as high as 400 to 500 feet. The western horizon, which can be noticed in some places in the southern valley, disappears in the middle portion of the valley in Jefferson County and makes its appearance again about ten miles northeast of Birmingham, and a few miles east of New Castle Station, coming in nearly direct contact with the Coal-measures of the Warrior field. The eastern Red Mountain, crossing the Alabama S. & N. R. R. at Grace's Gap, turns in a northeastern direction and follows for a few miles up along the edge of the Cahaba coal-field, while the western ridge follows within a mile of the Warrior field. Further north, and near the southern extremity of the Sand Mountain, the Eastern Mountain gets more irregular in its contours, showing chiefly a chain of high mountains and knobs. Around the Sand Mountain another exposure of the Clinton group occurs, branching off northwest and northeast around the Sand Mountain and forming in Murfrees' valley the easternmost occurrence of this group, and in the valley, between Sand Mountain on one side and Cahaba coal-field and Lookout Mountain on the

other side (which is the northeast extension of Jones', Roup's, and Will's valley), its westernmost occurrence. The thickness of the strata or veins of the red ore in the Clinton group varies very much. While the ore in the Clinton group in Pennsylvania does not show more than about two feet, the thickness of the strata steadily increases as the great Appalachian valley is followed southeast to Alabama. In Virginia, in the Cumberland valley, I measured not far from Bigstone Gap 7 feet 2 inches of the Clinton ore, of which 2½ feet are of very good quality. Entering Alabama from the Georgia State line and following the extension of Jones', Roup's, and Will's valley along the Alabama Great Southern R.R., we find the two Clinton horizons on the northwest side of the valley. The eastern ridge or Red Mountain follows here within half a mile the A. G. S. R.R., and has a distance of 2 to 2½ miles from the western ridge. The Clinton group of the eastern ridge shows here in De Kalb County, and west of Valley Head and Fort Payne stations, not more than 3 to 4 feet of ore in three different strata. About the same thickness of the red ore may be found in the western ridge.

The following is a section of the strata in the eastern ridge west of Valley Head and Fort Payne in De Kalb County.

1. Ore (soft),		9 to 14 inches.
Shale and Sandstone,	2 to 8 feet.	
2. Ore (soft),		12 to 15 inches.
Sandstone and Shale,	20 to 30 ft.	
3. Ore (harder),		15 to 20 inches.
Total ore,		36 to 49 inches.

Further southwest, in Etowah and St. Clair counties, west from Atalla and Springville, the thickness of the strata of the red ore in the eastern Red Mountain is greater. One stratum is from 2½ to 4½ feet thick. About the same thickness can be found further southeast in Jefferson County and northeast of Birmingham. The greatest thickness of the Clinton ore is reached south of Birmingham, where the S. & N. R.R. runs through a gap of the eastern Red Mountain called Grace's Gap. Half a mile southwest from Grace's Gap the mines of the Eureka Furnace Company are located. The red ore appears here in four different strata, having an aggregate thickness of more than 30 feet of ore, a thickness unsurpassed in North America so far as my knowledge goes.

The following is the section of the Clinton ore in the eastern Red

Mountain in Jones', Roup's, and Will's valley, at the mines of the Eureka Company, one-half mile southeast of Grace's Gap:

1. Limestone and sandstone,	
2. Sandy ledge of red ore (30 to 32 per cent. metallic iron),	10 to 12 feet.
3. Sandstone and shales,	15 "
4. Soft ore (51 to 54 per cent. metallic iron),	$4\frac{1}{2}$ "
5. Hard ore (about 40 per cent. metallic iron),	17 to 18 "
6. Sandstone,	3 "
7. Medium soft ore (Irondale vein, about 50 per cent. metallic iron or more),	3 "
8. Limestone (siliceous),	
9. Limestone (good),	
Total red ore,	$34\frac{1}{2}$ to $37\frac{1}{2}$ feet.

Following the mountain southwest, we find the principal stratum from 11 to 13 feet thick, only two to three miles from the Eureka mines, but running down to 5 to 6 feet in about as many miles, and showing still further southwest only about 2 to 3 feet.

The western Red Mountain, which disappears in the middle part of the valley, in Jefferson County, shows in the southern portion of Jefferson County several strata, but none over $1\frac{1}{2}$ to $2\frac{1}{2}$ feet thick. Northwest of Birmingham, along the eastern edge of the Warrior field, different strata of the ore can be found in the western mountain, but also not thicker than $1\frac{1}{2}$ to $2\frac{1}{2}$ feet. The same thickness can be found further northeast in Murfrees' valley. The eastern ridge of the Clinton group in Murfrees' valley shows greater thickness of the veins than the Western Red Mountain. I give the following section from the lower Murfrees' valley, 4 to 5 miles above Village Springs:

1. Ore (hard), about 35 to 40 per cent. metallic iron,	5 feet or more.
2. Interval,	5 "
3. Ore (soft), good, about 50 to 55 per cent. metallic iron,	2 " 2 inches.
4. Interval,	60 "
5. Ore (medium hardness), good, about 50 to 55 per cent. metallic iron,	2 " 4 "
6. Interval,	3 " 6 "
7. Ore (medium hardness), good, about 50 to 55 per cent. metallic iron,	2 " 6 "
Total ore,	12 feet.

Of the brown ore the largest deposits are known in the southern parts of Jones', etc. valley, near Woodstock, Tannehill, and Green Pond, and in Murfrees' valley, a few miles northeast from Chapultepec P. O.

The character of the red ore varies in hardness and chemical constitution. Two kinds of ore are noticed—the soft and the hard ore. The hard ore differs from the soft ore principally in its lower percentage of metallic iron and higher percentage of lime carbonate.

Brown's Valley or Blountsville Valley (the Sequetchee Valley of Tennessee).—Very little is to be said concerning the geological formation and the minerals of this valley, so far as it lies in Alabama. The anticlinal upthrow has here not reached the same height as in the above described valleys; the break exposed only the Subcarboniferous rocks, except in the lower part of the valley around Blount Springs and near the southwestern end of the valley where the higher Silurian rocks can be found.

The future importance of Alabama as a manufacturing State lies in the middle zone, with its great wealth of iron ore, and its supplies, near the ores, of good coking coals. Improvements in transportation (including the perfecting of water-transportation to the Gulf) will be necessary to enable this region to realize fully the advantages with which it has been endowed by nature.

The Metamorphic Region.—The metamorphic region in Alabama covers the counties or parts of counties: Chilton, Coosa, Talledega, Calhoun, Cleburne, Lee, Tallapoosa, Elmore, Clay, Randolph and Chambers, with about 5000 square miles of area. The rocks of this region are partly metamorphosed Lower Silurian rocks (Calciferous, Potsdam, and Acadian), partly Upper Azoic rocks (Huronian) and perhaps Lower Azoic rocks (Laurentian). The character of the different rocks and minerals of the metamorphic region may be best given by a short profile at a right angle to the strike of the rocks. The strike of the rocks (according to the formation of this region, which is the southwestern extremity of that part of the Appalachian chain known farther northeast under the name "Blue Ridge") is from the northeast to the southwest, the dip being mostly to the southeast, at very high angles, or nearly vertical. Going in a right angle to the strike, that is from northwest to southeast, we find in Alabama the following zones, which, however, cannot be sharply separated.

1. *Silurian.*—Crystalline limestones, conglomerates, heavy quartzites and slates (often gold-bearing), semi-metamorphosed.

2. *Huronian.*—Mica slates and schists (with garnets), limestones, coarse-grained granites, diorite, quartzites and clay slates (sometimes gold-bearing); the mica schists often alternating with gneisses; as-

sociated with graphite and graphitic slates, itacolumite, specular ore and brown hematite, etc.

3. *Huronian or Upper Laurentian.*—Gneisses (micaceous and hornblendic), granite, diorite, mica schists, quartzites, slates (sometimes gold-bearing), associated with chloritic schists and steatites, mica with turmaline crystals, etc. Some of the granites have the characteristics of eruptive rocks.

The following minerals may be mentioned as more or less frequent in this region:

Specular iron ore, occasional, in small pockets, especially in itacolumite; brown hematite, in masses and local deposits in the quartzites and mica slates, but not, so far as known, in large deposits (see analyses in tables below of brown hematite from Chilton county); titanic iron, as accessory constituent in itacolumite and slates; magnetite, in fragments, and an alleged small vein in Coosa county; pyrolusite, associated with brown hematite in considerable quantity, in Chilton county; pyrite, in extensive deposits (according to Professor Smith), in Clay county; copper ore, "black oxide," with galena in small quantities in quartz, in Chilton county, and also with chalcopyrite at Wood's mines in Cleburne county (now abandoned), and in some other localities; gold, in most of the streams, where it has been washed for forty or fifty years past by the inhabitants, and also in auriferous pyrite in Clay county, etc., but no gold mines now working; graphite and graphitic slates, in large but impure beds; asbestos, in Coosa and Tallapoosa counties; mica, formerly mined in Chilton county but now abandoned, because it was too much mixed with turmaline; corundum, in occasional crystals found in Chilton, Coosa and other counties; zircon and rutile, as frequent accessory minerals; tantalite, a rare mineral, yet not infrequent near Rockford (analysis by Dr. J. Lawrence Smith: tantalic acid, 79.65; tungstic acid, 1.10; stannic acid, 0.87; protoxide of manganese, 3.72; protoxide of iron, 13.51; oxide of copper, 0.89; specific gravity, 7.305 to 7.401); kaoline, in an extensive deposit near Louisa, Randolph county (according to Tuomey), and also in Coosa county, near Locopatoy and Notasulga; jasper, in Chilton and Coosa counties.

On the soils of the metamorphic region I will say nothing here, since the agricultural aspects of Alabama geology do not directly concern the Institute.

III. The Southern Zone.

This zone comprises the remainder, that is to say, about four-sevenths of the total area of Alabama. It presents the Cretaceous, Tertiary, Diluvial and Alluvial formations; and since it is not the scene of mining operations, or especially interesting to mining engineers (except as to a few deposits of brown hematite and iron-conglomerate in the drift, the brown coal and burr-stone of the Tertiary, and the artesian wells which pass through the Cretaceous "Rotten Limestone group," to find water in the Eutaw clays), I will pass it without further comment.

The following tables, compiled from many sources, give detailed information concerning the ores, coals, etc., described in the preceding pages.

TABLE I.

Analysis of Bituminous Coals of the Cahaba Coal-field.

Number.		County.	Analyst.	Sp. Gr.	Moisture.	Vol combustible matter.	Fixed carbon.	Ash.	Sulphur as sulphate	Sulphur as sulphuret of iron
1	Cahaba vein	...	Rothwell	1 220	1.660	33.280	63 040	2 020	0 097	0 428
2.	Holt's mine	..	"	1 290	1 580	32.600	62 620	3 200	0 223	0 727
3	Black shale vein—McGinnis	..	"	1.290	1 910	32.650	63.910	1 530	0.071	0.559
4.	Moyle's seam	...	"	1.380	1 930	32.840	59.640	5.590	1.001	2.779
5	Little Pittsburgh vein	.	"	1 290	2.050	33 470	62.200	2.280	0 118	0.523
6	Conglomerate vein	...	"	1.280	2 130	30.860	64.540	2 470	0 320	1.160
7.	Helena vein (No. 1.)	...	"	1.120	2.540	29.440	66 810	1.210	0 073	0.455
8	Coke vein	...	"	1.280	1 780	30 600	66 580	1 090	0 085	0.479
9	Gholson vein	...	"	1 250	2 140	31.920	63.680	2 260	...	...
10.	Montevallo vein	...	"	1.350	2 130	27 030	66.220	4 620	0 144	0.388
11.	Gould seam	...	"	1.300	1.340	28.960	60.580	9.120	0.090	0.730
12.	Beaver Dam seam	...	Wuth	.	0 300	31.360	65.450	2 810	...	0.080
13.	Helena mines (No. 2).	..	Lupton	1.320	1 740	35.480	58.960	3 820	...	0 900
14.	Wood's Pit (n Montevallo)	Shelby	Mallet	1 294	0.760	35 510	57.420	6 310	...	...
15.	Pushmattahaw beds (n. Mont'o)	Shelby	"	1.304	0.790	36 680	57.230	5.300	.	
16	Wadsworth seam	..	......	...	.	34 600	60.530	4 870	...	0.680

TABLE II.

List of Bituminous Coals of the Warrior Coal-field Analyzed.

No.		County.	Analyst.
1	Lower part of the Townley bed	Walker.	Henry McCalley.
2	Upper part of the Townley bed	"	"
3	Lower part of the Jagger bed	"	"
4	Upper part of the Jagger bed	"	"
5	Upper part of the Baker bed	"	"
6	Lower part of the Baker bed	"	"
7	Phillip & Cordell bed (No. III)	"	"
8	Phillip & Cordell bed (No II)	"	J. B Durett
9	Jim Hawthorne bed (No I)	"	Henry McCalley.
10	Coal from Sect. 4, Townsh 16, Range 6 W	"	"
11	Coal from Sect 8, Townsh 15, Range 6 W	"	"
12	Robinson bed, sample No 1 (No II)	"	"
13	Robinson bed, sample No 2 (No II)	"	"
14	Robinson bed (No I)	"	"
15	Beechy Hollow bed	"	"
16	Baley bed, sample No 1	"	"
17	Baley bed, sample No 2	"	"
18	Baley bed, sample No. 3	"	J B Durett
19	Coal from Sect 24, Townsh 16, Range 7 W	"	Henry McCalley.
20	Upper part of Village Creek bed	Jefferson	"
21	Lower part of Village Creek bed	"	"
22	Newcastle vein	"	Dr. Otto Wuth.
23	Black Creek vein, sample No. 1	"	Dr W Gesner.
24	Black Creek vein, sample No. 2	"	Prof N. T Lupton.
25	Coketon vein, upper part	"	Henry McCalley.
26	Coketon vein, lower part	"	"
27	No III. of the Fork Shoals profile	Walker.	J. B. Durett.
28	No. III of the Fork Shoals profile	"	"
29	No II. of the Fork Shoals profile	"	Henry McCalley.
30	No. II. of the Fork Shoals profile	"	"
31	No. I. of the Fork Shoals profile.	"	"
32	Cave Hollow bed	"	"
33	No I of the Blue Creek profile, sample No 1	Tuscaloosa.	J B. Durett.
34	No I of the Blue Creek profile, sample No 2	"	Henry McCalley
35	No II of the Blue Creek profile, sample No 1	"	J B. Durett.
36	No II. of the Blue Creek profile, sample No 2	"	"
37	Cannel Coal, Daniel's Creek	"	Henry McCalley.
38	Block coal-seam	"	"
39	Double coal-seam	"	"
40	Manley seam	"	"
41	University seam, Jim Black's branch	"	"
42	University seam, University mine	"	J B. Durett.
43	University seam, Goree bed	"	Henry McCalley.
44	Prude's lower bed	"	"
45	Chamber's mine	"	"
46	McLester Shaft, near Tuscaloosa	"	"
47	Asylum Shaft, near Tuscaloosa	"	"
48	Burnett bed	Marion.	"
49	Mineral charcoal	"	"
50	Bituminous slate	Fayette.	"
51	Warrior coal, likely the Warrior vein	Jefferson	....
52	Woodward's Coal, northwest from Wheeling. Said to be the Coketon vein	"	Eugene A. Smith.

TABLE II.—*Continued.*

No.	Spec. Gravity.	Sulphur.	Moisture	Volatile Combustible Matter.	Fixed Carbon.	Ash.
1	1 31	0 71	3.007	29 084	63 352	4 557
2	1 45	1 744	2.96	26 162	44 516	26 362
3	1 14	0 36	2 238	29 037	50 638	17 987
4	1 233	0.574	3 091	29 041	56.537	11 328
5	1 324	0 695	6.355	31 086	60 665	1 894
6	1 285	1.331	2.578	35 164	59 348	2 910
7	1 290	0 649	3 098	34 552	60.745	1 605
8	1 318	3 070	2 052	38 078	55 265	4 605
9	1.383	0 516	2 969	29 784	60 598	6 649
10	1 401	0 482	3 799	26.217	57 316	12 668
11	1 380	0.586	2 213	28 987	56 454	12 355
12	1 371	0 580	2.454	27 007	57 650	12 989
13	1 364	0 599	2 703	26 600	56 367	14 330
14	1.365	0 711	1 848	28 365	58 213	11 574
15	1.437	0 527	6.952	27.065	55 640	10 343
16	1 278	0 690	2 702	29.564	64.818	2 916
17	1 339	0 603	5 715	28.095	62.612	3 578
18	1 416	1 236	1 533	30.405	51.962	16 100
19	1 339	1 105	4 535	26.407	56 890	12.218
20	1 391	0 521	4 175	22 415	62 482	10.928
21	1.312	0 604	1.525	26.170	66 020	6.285
22	1.380	0 640	0 500	28.240	59 690	10 920
23	1 360	0 100	0 120	26.110	71 640	2 030
24	1.290	0 320	1 360	31.796	64 710	1 820
25	1.330	1 224	1 474	32 288	59 503	6 735
26	1 278	0 612	1.529	30 683	63.683	4 102
27	1 325	0 793	4 976	27 169	62 135	5 720
28	1.268	1.131	1 475	34 271	59.128	5 126
29	1 280	1 506	1 442	27 211	66.000	5 347
30	1.310	1 076	1.398	30 647	62 183	5 772
31	1.336	0 722	3.560	26 566	64 288	5 646
32	1 330	1.945	1 258	26.253	59.896	12 594
33	1.280	0 801	2 514	32 093	61 886	3 507
34	1 317	0 608	2.179	32 855	59 820	5 146
35	1 329	0.835	0 778	33 271	61.082	4 869
36	1.282	0 798	2 391	33 865	59 069	4 675
37	1.348	2.752	0 830	36 207	48 319	14 644
38	1 411	1 613	2 239	34 606	50 375	12 780
39	1 304	2 129	1 810	34.029	58 241	5 291
40	1 277	0 752	2.004	33.833	61 872	2 291
41	1 303	0 765	7.285	28 989	54.522	9.204
42	1 298	1.038	1 833	36 233	54.534	7 400
43	1 386	0 870	2.062	31 103	55.495	11.340
44	1.327	0 626	5 426	31 952	59.455	3.167
45	1 281	2 380	1.838	30 682	64 339	3.141
46	1 283	1 861	2.245	35 130	55.301	7 324
47	1.397	1 867	1 892	32.011	55 364	10.733
48	1.102	1 730	3 694	35 380	58.517	2.409
49	1.551	..	1 753	15 285	79 215	3.747
50	1 099	1 501	0.268	75.688	7 284	16.742
51	. ...	... .	.. ..	32.370	64 990	2.640
52	. . .	. . ..	......	31 224*	63 458	5.318

* Including moisture

TABLE III.

List of Alabama Brown Hematites Analyzed.

No.	Locality.	County.	Formation.	Analyst.	Remarks.
1	Near Russelville.	Franklin.	Subc.	H McCalley.	
2	" "	"	"	"	
3		Cullman.	Carb.	E. J. Schmitz.	Clay iron-ore
4	East of Cullman.	"	"	H. Endemann	
5	S W of Cullman.	"	"	C. A Mohr	
6		Winston.	"	H. McCalley.	Carbonate.
7	Near Vernon	Lamar.	Drift.	"	Sample 1.
8	" "	"	"	"	" 2.
9	" "	"	"	"	" 3
10	Near Mt Pinson.	Jefferson.	Silur.	E. J Schmitz	
11	Green Pond	Bibb.	"	A. W Kinsey.	Sample 1.
12	" "	"	"	W T. Roepper.	" 2
13	" "	"	"	"	" 3.
14		Tuscaloosa.	"		
15	Woodstock.	Calhoun.	"		
16	Shelby Iron Works.	Shelby.	"	C F Chandler	
17	" " "	"	"	"	Roasted
18	N E of Montevallo	"	"	E Smith.	Sample 1.
19	" "	"	"	"	" 2.
20	N. E of Helena.	"	"	"	
21	Near Alpina	Talladega.	"	J. B Britton.	
22	Lay Bank.	"	"	"	
23	Irona Bank.	"	"	"	
24		Bibb.	"	"	Sample 1.
25		"	"	"	" 2
26		"	"	"	" 3.
27		"	"	"	" 4
28		"	"	"	Pipe-ore.
29		"	"	"	
30	H. Glascock's.	Chilton.	Metam.	M. M. Duncan.	
31	Gallihorn's.	"	"	"	E of Cooper's.
32	"	"	"	"	N of Mill.
33		"	"	Lupton.	
34		"	"	E. Smith.	Sample 1.
35		"	"	"	" 2.
36		"	"	"	" 3
37		Coosa.	"	"	Pipe-ore.
38	West of Briarfield.	Bibb.	Silur.	"	Do., sample 2.
39	" "	"	"	"	Sample 1.
40	Woodstock St.	Tuscaloosa.	"	Lupton.	" 2.
41	" "	"	"	"	" 3.
42	" "	"	"	"	
43	Springville.	St. Clair.	"		
44	Oxford	Calhoun.	"	Mallet.	
45	Above Spencers'.	"	"	"	
46	Benton.	"	"	"	
47	Bluff Creek.	N. Alabama.	Subc.	"	
48		Jefferson.	Carb.	"	Clay ironstone.
49		Walker.	"	"	"
50		Tuscaloosa.	Silur.		

TABLE III.—*Continued.*

No.	Specific Gravity	Hygroscopic Moisture	Combined Water.	Silicious Matter, etc	Sesquioxide of Iron.	Sesquioxide of Manganese.	Alumina.	Lime.	Magnesia.	Sulphur.	Phosphoric Acid	Phosphorus.	Metallic Iron.
1	3 616	1.648	10.444	3 159	84 696	0 087	0.220	0 440	0 025	0 054	0.765	0.334	59 287
2	3 800	0 833	11 849	2 864	85 514	0 188	1.411	0 407	0 045	0.085	0.760	0 332	58 459
3	..	..	.	19 382	57 667	..					.	.	40 367
4	.	..	..	9.060	74 550	..	5.310	0 330	0 190	.	.	...	52 190*
5	...				68 571		..	.				trace	48 040
6	3.563	0.967	1 437	5 209	7 918†	0.186	4.046	2 418	3 486	0 317	0 341	0 149	35 000
7	3 421	1.777	12 466	4 371	78 284		0 760	0.809	0 391	0 129	0 615	0 268	54 800
8	3 461	1 468	12 372	4 367	80 053	0 188	0 221	0.407	0 450	0 085	0 624	0.272	56 037
9	3 392	3.843	8.155	4 506	81 173	0 073	1 341	0 298	0 032	0 138	0.268	0 117	56 821
10	...	...	...	22 150	70 850		..	...		.	...	..	49 595
11	..	.	11.620	11 450		...	...	..	..	.	...	.	38 550‡
12	.	..	13 090	3.100	84 250	.	trace	...			...	trace	58 975§
13	...	...	8.550	34.030	57 460		trace		..			trace.	40 222§
14	..	..	10 250	3.550	76.860	trace.	2 950	**		.	0.350	0.153	53 802
15		..	.	9 230		....	.	††				.	50.200
16	.	..	9 250	7 060	78 860	1 490	2 370	0 580	trace	0 140	0 370	0 160	55 202
17	.	.	3 800	11 740	81 350	0 750	1 590	0 570	0 120	0 160	0 110	0 050	56.945
18	4 310	..	11.190	3 090	84 100	trace	0 270	1 020	0 080	0 460	0.200	0 090	58 870
19	3 610	...	11 270	13 490	73 400	0 000	1 030	0 380	0 080	0 280	0 330	0 140	51.408
20	...	.	11.980	1 500	84 030	0 200	0 200	0.240	trace	0 030	1.220	0.490	58 821
21	..	..		0 760		.		..	.	0 000	...	1 520	56 740§
22	.	..	11.860	7 580	77 540	...	2 070	0.070	0 030	0 000	0.290	0 130	54.278§§
23	..	..	11.520	11 710	68 930	.	3.590	0 100	0 050	0 000	0 130	0.060	48.251§§§
24	.		10.490	6 040	79.930	0 920	1.430	0 070	trace	0 000	1.010	0 450	55.951
25	..	...	7.410	3 060	82.840	0 950	0 350	1 020	0 190	0 450	0 550	0 240	57.988
26	..	..	12.410	7.840	.	3.360	1 470	0.110	0.120	0 000	1.350	0.580	66.758
27	.		12.720	5 610	..	0.110	1 360	0 060	0 100	0 000	1.300	0 570	71.556
28	3.780		8.540	2 340	87.490	0.120	0 270	0 820	0 330	0 480	trace.	.	66 758
29	...		10.490	14 110	.	0.410	2 650	0.110	0 070	0 000	0.800	0 349	64.826
30	..	...	.	10 920	62.840	trace	..	...	.	0.112	...	0 908	43.988
31	.	..	..	5 178	80 040	.	.	....	.	0 071	...	0 610	56.028
32	..	..		4 140	80.840		.	...	..	0 068	.	0.896	56.588
33	.	...	10 630	5.580	80 430	0.680	1 600	...	..	0 140	0 920	0.402	56 301
34	3 140	..	7 510	40 620	46 120	0.290	1 850	0.390	0 750	0.070	0.870	0 380	32 284
35	3 030	...	7 160	1.610	88.120	0.020	1.350	0.400	0 020	0 020	0 330	0 144	61.684
36	3.670	...	10 900	9.260	78.270	0 500	1 650	0.440	0 220	0.030	0 230	0 104	54.789
37	3 400	...	9 790	1.780	83.130	0.190	3 670	0 500	0 040	0.610	0 760	0 332	58.191
38	3 780	.	8.540	2 340	87 490	0.120	0 270	0 820	0 330	0.480	trace	.	61 243
39	3 810	.	7 410	3 060	82 840	0 950	0.350	1 020	0 190	0.450	0 550	0.240	57 988
40	3 750	.	11 350	2 460	84.460	0.330	0 910	0 260	0.040	0.140	0 580	0.253	59.122
41	3 560	..	12 140	12 160	75.040	0.000	0 300	0 410	0 060	0.140	0 000	...	52.528
42	3 430	...	11 550	2.980	82 830	1.020	1 390	trace	0.120	0.140	trace	.	57.981
43	...	...	3 790	7 210	83.430	0 540	3 380	0 881	.	trace	0.334	0.146	58 410
44	3 691	..	13 360	1.190	84 320	0 410	0 890	.	..	...	trace.	.	59.024
45	3 804	...	12 780	0.150	84 370	trace	1 240	0 080	..	...	0 560	0 245	59.060
46	3 288	...	12.700	3.210	82.450	0 630	0 770	trace	trace.	..	trace		57.71
47	3.262	...	12 370	5 580	80 650	0 260	0 090		trace.	.	0 920	0.402	56.45
48	3 495	...	1 170	6.370	0 430	..	0 060	***	..	..		.	42.230
49	3.385	..	0 840	14 940	1.200	...	0.130	†††	...	..	..	..	35 040
50	...	*..	.	9.440	75 447	..	3.609	0.460	.	...	..	..	52.813

* With 0.070 metallic manganese.

† With 42.082 protoxide and 31.908 carbonic acid. ‡ With 11.440 metallic manganese.

§ Traces of metallic manganese. ** Carbonate of lime, 5.500.

†† Carbonate of magnesia, 0.810 §§ Metallic manganese and loss, 0 560.

*** Carbonate of manganese, 3.040, carbonate of iron, 86.350; carbonate of lime, 2.120; carbonate of magnesia, 0.120.

††† Carbonate of manganese, 1.530; carbonate of iron, 70 840; carbonate of lime, 2 311; carbonate of magnesia, 7.640. §§§ Metallic manganese, 3 770.

TABLE IV.

List of Alabama Blackband, Magnetites, and Red Hematite Ores Analyzed.

No	Locality.	County	Formation	Analyst.	Remarks.
51	Pierce's Mine.	Jefferson.	Carb.	A. W. Kinsey	Blackband, raw
52	" "	"	"	"	Blackband, calcined.
53	" "	"	"	"	" coked.
54	Hoehne's Mine.	"	"	S. Pittsb. Co.	" "
55	" "	"	"	"	" residue.
56	Newcastle St.	"	"		" raw.
57	" "	"	"		" calcined
58	McIlvain.	"	"	Lupton.	
59	Upper Cahaba.	St. Clair.	"		Siderite
60	Near Childersburg.	Talladega.	Metam.	Hough.	Magnetite.
61	" "	"	"	"	"
62	Wm. Andrews.*		"	Mallet.	"
63		Clay.	"	Stubbs.	"
64	Near Mt Pinson.	Jefferson	Silur.	E. J. Schmitz.	Red hematite.
65	Mines' Gap		"	Otto Wuth.	"
66	9 m. ab. Mines' Gap		"	"	"
67	1½ m bel " "		"	"	"
68	Near Jonesboro.	Jefferson.	"	Chauvenet	Red hematite, sam. 1.
69	" "	"	"	Blair.	" " " 2.
70	" "	"	"	"	" " " 3.
71	Iron Mountain.†	Shelby	"	J. B Britton.	" " " 1.
72	" "	"	"	C. F. Chandler.	" " " 2.
73	" "	"	"	Eug. Smith.	" " " 3.
74	" "	"	"	"	" " " 4.
75	" "	"	"	Mallet.	" " " 5.
76	Gaylesville.		"	"	Red hematite.
77	Pierce's Mill.	St Clair.	"	"	"
78	David Hanby's.	Blount	"	"	"
79	Potter's.	Jefferson.	"	Lupton.	Red hematite, top lift.
80	"	"	"	"	" lower lift.
81	Eureka Mines.‡	"	"		" top lift (soft).
82	" "	"	"		" low. lift (hard)
83	Pearson's.	"	"		Red hematite.

* Near Oak Bowery. † Near Columbiana. ‡ Near Oxmoor.

TABLE IV.—*Continued.*

No.	Specific Gravity.	Hygroscopic moisture.	Combined Water.	Siliceous Matter, etc	Sesquioxide of iron.	Sesquioxide of Manganese	Alumina.	Lime.	Magnesia.	Sulphur.	Phosphoric Acid.	Phosphorus	Metallic Iron.
51	..	2.750	..	3 300		.	3.530	..	.	trace.	0 494	0 216	21 800*a*
52	..	..	..	7 950	74.961	...	8 500	3 390	4.008*b*	trace.	1 191	0 520	52 473
53	..	.	*c*	5.930	.. .	..	6 340	3 540	1 980*b*	trace.	0 860	0.370	39.150*r*
54	.	...	35.640*d*	.	...	...	.	.	.	..	...	.	
55	.	..	*e*		trace.	.		3 600	2 570	..	.	0.300	24 290
56	.	2.260		5.330	.....	trace.	5.50	... ..	...	trace	0 630	0.275	36.380*f*
57	..	...	32 930	.		.	..	.	.		..	..	55 280
58	2.420	.	24.250	0 710	8.030	0 000	1.180	2.750	0 610	trace	trace	.	35 750*g*
59	..	.	32.518	2 740	..	*p*	5 544	1.250	0 674		0 646	0 282	39 230*h*
60	.	12 000	.	24 600	*s*	*u*	*u*	*u*	*u*	0 040	0 050	0 022	...
61	..	0.080	...	10 300	*t*	.		*v*	*v*	0 060	0 150	0 065	...
62	4.827	..	.	0 540	61.370*w*	..	trace	.....	0 080		.		65 360*i*
63	3.850	..	0.910	3 750	57.520*x*	6 240	6.000	....	0.000	0 000	trace.	...	60.380*j*
64	..	.	...	19.640	71.730	..		..			.	.	50.210
65	.	.		19 080	76 260	..	1 420	2.280	0.430	.	0 530	0 231	53.362
66	..	..	..	17.220	78.470	...	1 590	1 870	0.360	..	0.490	0 214	54.929
67	..	..	..	17 890	77.320	..	1 750	2 100	0.430	...	0 510	0 223	54.124
68	..	..	2.960	12 180	80 920	...	2 680	0 280	0 390	..	0 292	0 127	56 644
69	.	..	3.310	39 150	54 510	..	1 810	0 350	0 230	.	0 312	0 136	38 157
70	..	.	0.620	60 050	37 080	..	1 710	trace.	0.240	trace.	0.086	0 038	25 956
71	.	..	..	29 060	63 729	..	3 660	...	...	0 000	..	0 300	44.610*o*
72	..	...	.	23.450	70 090	..	.	.	.	0 110	0.770	0 336	49.080
73	3 860	...	1.260	30.030	60 790	0.140	5.880	1 580	0 360	0 900	trace	...	42 553
74	3 430	...	7.450	16.240	70 390	0 260	3.310	0 940	0.310	0.600	1.390	0 607	49 273
75	3 873	...	.	20.740	76 870	0.510	1.550	..	...	..	trace.	.	53.810
76	2 964		...	13.440	82.670	0.400	3.090	trace.		..	0.060	0.026	57.870
77	3 168	...	...	27 740	51 460	0 240	2 320	*k*	...	...	0.160	0.069	36.022
78	3.230	.	....	37.580	61 870	0 050	0.260	0 030	.	.	0 030	0 013	43.309
79	..	...	..	14.560	74 980	.	..	...	...	..	1 050	0 570	52.486
80	...	..	..	9.040	58 300	...		*l*		..	0 458	0 249	40 810
81	...	...	2.750	13.190	77.071	trace.	3 350	0.840 *m*		...	0.510	0.223	53 950
82	.	.	3 500	15.250	71 900	...	2 140	3 500 *n*		...	0 760	0.332	50 330
83	.	..	..	9 780	81 580	*q*	3 302	2 060	0.690	trace.	..	0.410	56.810

a Carbonates: of iron, 45.159; of lime, 2 518; of magnesia (*b*), 2 102; bituminous coal, 40.147, fixed carbon, 23.054 *b*. Including sesquioxide of manganese. *c*. Fixed carbon, 42 200.

d Including volatile matter. This analysis shows 33 350 fixed carbon.

e. Fixed carbon, 51.810.

f. Carbonates: of iron, 75.750, of lime, 5.050, of magnesia, a trace, bituminous coal, 5.100.

g. Carbonate of iron, 62.350. *h* Carbonate of iron, 57.048. *i*. Titanic acid, 9.210.

j Titanic acid, tested for and not found. *k*. Carbonate of lime, 17.890.

l. Carbonate of lime, 12 550.

m. Carbonates: of lime, 1.500; of magnesia, a trace.

n Carbonates: of lime, 6.250; of magnesia, a trace. *o* Metallic manganese, 1.000

p. Monoxide of manganese, 0 320. *q*. Monoxide of manganese, 0.270.

r And 34.700 protoxide of iron. *s*. Protoxide and sesquioxide of iron together, 74.430.

t. Protoxide and sesquioxide of iron together, 83.320

u. Oxide of manganese, alumina, lime, and magnesia together, 0.320.

v. Lime and magnesia together, 0.220

w. Also, 28.800 protoxide of iron *x* Also, 25.880 protoxide of iron.

TABLE V.

List of Limestones, Dolomites, and Marbles Analyzed.

No.	Substance.	Locality.	County.	Formation.	Analyst	Remarks.
1	Limestone.	Blount Springs	Blount.	Silur	Kinsey	Sample 1.
2	"	" "	"	"	"	" 2
3	"	" "	"	"	"	" 3.
4	"	" "	"	"	"	" 4.
5	"	" "	"	"	"	" 5.
6	"	" "	"	"	"	" 6
7	"	Truesville.	Jefferson	"	Lupton	
8	"	Longview	Shelby.	"	E. Smith.	Sample 1.
9	"	"	"	"	"	" 2.
10	"	"	"	"	Chandler.	
11	"	Shelby I. W'ks.	"	"	Britton.	Sample 1.
12	"	" "	"	"	"	" 2.
13	Dolomite	" "	"	"	"	" 3
14	Limestone.	" "	"	"	"	" 4.
15	"	" "	"	"	Stubbs.	" 5.
16	"	Columbiana	"	"	Chandler.	
17	Dolomite.	Ala. Furnace.	Talladega.	"	Britton	Sample 1.
18	"	" "	"	"	"	" 2.
19	Marble	Taylor's Mill.	"	"	Stubbs.	White.
20	"	" "	"	"	"	Blue
21	Dolomite.	Chewada Quarry.	Lee. *	"	"	Bluish-white.
22	"	" "	"	"	"	Sample 2
23	"	" "	"	"	E. Smith.	" 3.
24	"	" "	"	"	"	" 4.
25	"	Springville Quarry	"	"	"	Bluish.
26	Marble.	Herd's Upper Quar.	Talladega.	"	Mallet.	Snow-white.
27	"	Pratt's Ferry.	Bibb.	"	"	Gray, compact.
28	Limestone.	Clement's Mill.	*	"	"	
29	Dolomite	Colquitt's Quarry.	Talladega.	"	"	White.
30	Marble	Yonge's Quarry.	Macon.	Metam.	"	"
31	Dolomite.	Reese's Quarry	"	"	"	Grayish-white
32	"	Jones's Valley.	Jefferson.	Silur.	"	Brownish-white.
33	"	Chockoloko.	Calhoun.†	"	"	Yellowish-gray.
34	Limestone.	Huntsville	Madison.	Carb.	"	Grayish-brown
35	"	Ditto's Landing	‡	"	"	Bluish-gray.
36	"	Russell's Valley.	Franklin.	"	"	Yellow.
37	"	Chunnennugga.	Macon.	Cret.	"	Many fossils.
38	"	"	"	"	Mallet.	" "
39	Dolomite.	Jones's Valley.	Jefferson.	Silur.	E. Smith.	Sample 1.
40	"	" "	"	"	"	" 2.
41	Gypsum marl.		Clarke.	Tert.	"	
42	" "		"	"	"	
43	" "		"	"	"	

* Big Sandy Creek. † Near Boiling Spring. ‡ Tennessee River.

TABLE V.—*Continued.*

No.	Specific Gravity.	Carbonate of Lime.	Carbonate of Magnesia.	Ferric Oxide and Alumina.	Silica, etc	Phosphoric Acid.	Phosphorus.	Sulphur.	Water and Loss	Lime.	Magnesia.
1	...	93 508	3.675	0 550	0 733	0 034	..	trace.	*	52 364	1.749
2	..	89.135	5 250	1.125	2 650	0 090	.	trace	*	49.915	2 499
3	..	94 845	2.625	0 500	0 600	0 030	.	trace	*	53.113	1 249
4	..	92 725	1.890	0.450	3 300	0 035	...	trace	*	51.926	0 900
5	...	88 218	4.725	0 475	4.300	0 032	..	trace	*	49 402	2 249
6	...	95 717	1 680	0 425	0 700	0.028	..	trace	*	53.601	0.800
7	..	86.720	6 310	1 560	5 320	...	..		0.260	48 563	3.005
8	.	99 110	0 750	0 130	0 390	..	0.000	0.000	..	55 502	0 357
9	...	99.160	0.750	trace.	0 150	..	0.000	0.000	..	55.530	0.357
10	...	97 520	1.270	0 350	0.780	...	trace	0.000	0 080	54 611	6.048
11	...	93 770	2 480	1 010	2.090	...	0 000	0 160	0 360	52.511	1.190
12	..	98 910	0 580	0.630	1 080	...	0 000	0 050	0 000	55.900	0 276
13	.	67 550	24 910	3 580	3.460	.	0.030	0.020	0.450	37 828	1 186
14	..	95 400	0.940	0 680	2.250	...	trace	trace.	0.730	53.424	0 448
15	...	96 700	...	1.400	2 500	...	..		..	54 152	
16	...	89 030	3.910	1.080	4 880	...	0 000	0.130	0 840	49.857	1.862
17	...	55 350	34 580	1.480	7 750	.	...	...	0 840	30.896	16.456
18	.	61.860	33 550	1 090	2 860	...	...	...	0.640	34.642	15 976
19	2.700	95 250	0 620	1 150	2 950	.	.	...	...	..	...
20	2.680	94 400	0 410	0 750	4 650	...	.	..	...	..	..
21	..	59 230	36 340	3.340	1 030	.	..	...	...	33.169	15 976
22	..	58 290	38.150	0 860	2 240	..	.	..	...	32.642	17 305
23	2 890	57 730	41 580	0.120	0 890	.	...	...	...	32 329	18.167
24	2 750	49.720	32 030	0.270	17 440	..	.	...	..	27 843	15.252
25	2.910	72.940	22 520	0 730	3.930	...	..	..	...	40.846	10 724
26	2 712	99.470	0 380		trace.	...	..	...	...	55 703	0 181
27	2.711	96.220	0.660	0 200	2.790	...	...	...	...	53 883	0.314
28	2.717	96.370	1 720	0.250	1.040	...	..	..	..	53 967	0 819
29	2.846	55.480	44 040	0 310	0.090	...	...	...	...	31 069	20.971
30	2 855	55 420	43.950	0.190	0.400	...	...	...	...	31 035	20 907
31	2.860	59.330	38 390	0.330	1 810	..	...	..	...	33.225	18.281
32	2.793	56 680	40.250	0.440	2 490	...	...	...	...	31.741	19 167
33	2.853	55 170	43 390	0.890	0 450	.	..	...	...	30.895	20 662
34	2.676	64 030	1 760	2 030	31 910	trace.	...	...	...	35.857	0 838
35	2.702	92 170	0.610	1.290	5.570	trace.	...	...	...	51.615	0 290
36	2 592	99.210	0 390	trace.	0.300	..	..	...	...	55.558	0.186
37	...	53 660	0 970	0.490	44.600	..	..	...	..	30.050	0 462
38	...	88 820	2.180	0 940	7.200	0 230	0 100	...	..	49.739	1.038
39	..	55 394	42.755	0 717	1.122	0 016	..	..	...	31.021	20 359
40	...	58.715	45 951	0 146	0 146	0.009	..	...	.	32.880	21.881
			Gypsum †								
41	...	... ..	93 890								
42	...	12.000	67 830								
43	...	40 500	54.400								

* Determined by difference.

† $CaSO_4 + H_2O$ 2.

TABLE VI.

Analyses of Pig Iron.

Furnaces.	Kind of Fuel	Number of Iron	County.	Analyst.	Metallic Iron.	Graphitic Carbon	Combined Carbon	Sulphur	Phosphorus	Manganese	Silicon.	Undetermined.
Eureka furn's	coke.	No. I. Mill	Jefferson	..	..	3 579	0 782	0 005	0.169	...	3 235	...
" "	"	No I Foundry	"	...	..	2.670	0 135	0 012	0.075	.	3.705	
" "	"	No II Foundry	"	Hough	91 276	2.018	1 121	0.018	0 041	.	4.180	0.516
Alice furnace.	"	No. I Foundry	"	...	92 077	3.055	0 555	0.004	0 284	0 766	3 259	...
	"	No II. Foundry.	"	...	91 499	2 426	0 180	0 049	0 511	0 919	4.386	...

An analysis by Britton of charcoal blooms made from the ore of Irona banks, Talladega county, shows metallic iron, 99 020; carbon, 0 198; sulphur, 0.000, phosphorus, 0 122, manganese, 0.064, silicon, 0.265, undetermined and loss, 0.331

TABLE VII.

Analyses of Blount Springs Water.

Analyst, Dr. H Leefman.

SPRING No. 1.

Contains in 1 litre or 1000 gramm. of the water = 0.84580 gramm. solid matter, in which there was.

	Gramm.
Sodium chloride	0 52240
Sodium sulphate	0 01550
Calcium	0 00490
Calcium carbonate	0.12650
Magnesium carbonate	0 07410
Magnesium chloride	0.01370
Silica } Phosphates } Alumina }	0.05250
Iodides	trace.
Sulphur	0.03620

Analyst, Prof. W. C Stubbs

SPRING No. 4.

Contains in 1 litre or 1000 gramm. of the water = 0 962042 gramm solid matter, in which there was.

	Gramm.
Sulphuric acid	0.42800
Phosphoric acid	trace
Carbonic acid	0 155729
Chlorine	0.325117
Bromine	0.002111
Iodine	0 001878
Lime	0 060368
Magnesia	0 095190
Baryta	0 012710
Sesquioxide of iron	0.034000
Alumina	trace.
Sodium	0 036857
Potassium	0.063597
Lithium	trace.
Silica.	0 042800

TABLE VIII.

A. *Analyses of Copper Ores.*

No.	Variety.	Formation	County	Analyst.	Met. Copper.	Met Iron	Sulphur.	Insoluble Matter.	Silver	Oz in 2000 lbs.	Lead
1	Black ore.	Metam.	Chilton.	Endemann	25 970	.			0.340	99 140	0.840
2	Azurite.	"	Calhoun	Stubbs	10 620	23 100	29.200	4 000	...	..	..
3	Chalcopyrite.	"	"	"	34 950	not deter.	14 900	7 300	...	.	..
4	Malachite	"	"	"	19 240	25 200	23 100	16.600	..	..	...
5	Black ore	"	"	"	43 040	15 470	11 400	7 400	..	.	...
6	Cuprite	"	"	"	45 240	31 290	0 000	4 200		.	...

B. *Analyses of Iron Pyrites.*

No.	Variety.	Formation.	County	Analyst.	Silica.	Sulphide of Copper.	Sulphide of Iron	Met. Copper.	Gold.
1	Cupriferous pyrites	Metam.	Cleburne	Smith.	6.680	10.140	80.390	8.08	.
2	Pyrites.	"	Coosa.	Mallet.	...	..	.	..	good tr
3	"	Subc.	Cullman.	Endemann.	...	...	...	...	trace.

TABLE IX.

A. *Analyses of Kaoline.*

Locality.	Formation.	County.	Analyst.	Potash, Lime, and Magnesia.	Water.	Undecomposed Mineral.	Combined Silica.	Free Silica.	Alumina.	Sesquioxide of Iron.
Near Louina.	Metam.	Randolph.	Mallet.	0.720	15.090	14.280	19.850	17 440	31 920	trace.
" Jacksonville	Silur.	Calhoun.	Mallet.	1.030	13.380	0.900	39.750	4.850	38.920	0.780

B. *Analyses of Manganese Ores.*

No.	Variety.	Formation.	County.	Analyst.	Peroxide of Manganese.	Sp. Gr.
1	Pyrolusite.	Metam.	Chilton	Endemann.	71.220	.. ...
2	Psilomelane.	Silur.	Talladega	Mallet.	62.430	3.712
3	Psilomelane.	Metam	Randolph.	Mallet.	63.250	3.988

PROCEEDINGS

OF THE

TROY, NEW YORK, MEETING.

OCTOBER, 1883.

TROY MEETING.

COMMITTEES.

Local Committee of Arrangements.

R. W. Hunt, *Chairman.* Henry Burden, *Secretary.*

Finance Committee.

Charles W. Tillinghast. William Gurley. William Kemp.

Reception Committee of Members of the Institute.

C. T. Arnberg, I Townsend Burden, James A. Burden, Henry Burden, William F. Burden, Verplanck Colvin, Townsend Church, Erastus Corning, Chester Griswold, J. Wool Griswold, R. W. Hunt, Orleans Longacre, John H. Mars, Selden E. Marvin, Henry B. Nason, J. C. Platt, Jr., H. C. Shaw, J. M. Sherrerd, E. Ray Thompson, S. T. Williams.

The opening session was held in Keenan Hall, on Tuesday evening, October 9th. Mr. R. W. Hunt, of Troy, President of the Institute, and Chairman of the Local Committee of Arrangements, after calling the meeting to order, introduced the Hon. Martin I. Townsend, who delivered a cordial address of welcome to the Institute on behalf of the city of Troy. President Hunt called upon Dr. R. W. Raymond, who responded to this address on behalf of the Institute.

The following papers were then read:

Some Researches on Gold, by Dr. T. Egleston, of New York.

The Law of the Apex, by Dr. R. W. Raymond, of New York.

After the adjournment of this session the members enjoyed the hospitality of the Troy Club.

On Wednesday morning, October 10th, the members, and ladies accompanying them, made an excursion by carriages to the Fuller & Warren Company's Clinton Stove Foundry, the Rensselaer Merchant and Rail Mills of the Albany and Rensselaer Iron and Steel Company, and the works of the Burden Iron Company, after which the party were driven to "Woodside," the residence of Mr. James A. Burden, where they were charmingly entertained by Mr. and

Mrs. Burden. In the afternoon a visit was made to the Albany Iron Works and the Bessemer Works department of the Albany and Rensselaer Iron and Steel Company.

In the evening the second session for the reading and discussion of papers was held in Keenan Hall. The following papers were read:

The Bessemer Plant of the North Chicago Rolling Mill Company at South Chicago, by R. Forsyth, of Chicago.

Some Notes and Tests of an Open Hearth Steel Charge made for Boiler Plate, by A. E. Hunt, of Pittsburgh.

The Determination of Manganese in Spiegel, by G. C. Stone, of Newark, N. J. (read by the Secretary in the author's absence).

The Secretary then read invitations to the members of the Institute from Mr. Charles Kilmer, and from Messrs. W. & L. E. Gurley, to visit their works, after which the session was adjourned.

On Thursday morning the members and ladies of the party were taken in carriages to the shirt and collar factories, and the laundries connected therewith, of Messrs. Sandford & Robinson, Earl & Wilson, and Cluett & Brothers. Some of the members visited the works of the Messrs. Gurley, makers of mathematical instruments, and various places of interest in Cohoes. After this excursion the third séssion was held in Keenan Hall. The following papers were read:

A Description of a Chemical Laboratory erected in 1863, as an adjunct to the Experimental Steel Works at Wyandotte, Michigan, by W. F. Durfee, of Bridgeport, Conn.

The Peach Bottom Slates of Southeastern York and Southern Lancaster Counties, Pa., by Dr. Persifor Frazer, of Philadelphia.

A Systematic Nomenclature for Minerals, by H. M. Howe, of Boston.

A Water-gas Producer at Elgin, Ill., by P. Barnes, of Joliet, Ill.

Dr. Frazer showed at this session a platinum anode, which had been used in the electrolytic determination of copper, and which was covered with a dark deposit. Mr. Mackintosh thought the deposit was probably the peroxide of lead or manganese.

In the afternoon the concluding session of the Institute was held in Keenan Hall. The following persons, proposed for election as members and associates of the Institute, and approved by the Council, were then unanimously elected:

MEMBERS.

John L. Arts,	Troy, N. Y.
Richard P. Bloss,	Palmer's Falls, N. Y.
W. M. Chadwick,	Bergen Point, N. J.
P. E. Chapin,	Johnstown, Pa.
F. F. Chisolm,	Denver, Col.
Henry S. Church,	Troy, N. Y.
Torbert Coryell,	Lambertville, N. J.
A. H. de Camp,	Musquodoboit Harbor, Nova Scotia.
Thomas Dickson,	New York City.
John Don,	Troy, N. Y.
George C. Gardner,	Chicago, Ill.
Edward G. Gilbert,	Troy, N. Y.
Francis B. Griswold,	Troy, N. Y.
William Gurley,	Troy, N. Y.
W. B. Hammond,	Galena, Dakota.
Jonas S Heartt,	Troy, N. Y.
William R. Hills,	Albany, N. Y.
C. H. Joüet,	Roselle, N. J.
Edgar B. Kay,	Troy, N. Y.
Arthur H. Keller,	Brooklyn, N. Y.
William Kemp,	Troy, N. Y.
Edward O. Knight,	Troy, N. Y.
Paul F. Lobanoff,	Silverton, Col.
Harvey S. McLeod,	Troy, N. Y.
John Male,	Troy, N. Y.
William P. Mason,	Troy, N. Y.
Seeley Mudd,	Ste. Genevieve, Mo.
Francis A. Ostrander,	Troy, N. Y.
Robert Peele, Jr.,	Bloomfield, N. J.
Marion Randolph,	Albany, N. Y.
James B. Risque,	Silver City, Col.
E. J. Schmitz,	New York City.
Edwin E. Sluder,	Cerrillos, N. M.
Max Suppes,	Troy, N. Y.
George W. Swett,	Troy, N. Y.
Elwyn Waller,	New York City.
Walter P. Warren,	Troy, N. Y.
John F. Williams,	Troy, N. Y.
John J. Williams,	San Francisco, Cal.
Thomas W. Yardley,	Troy, N. Y.
Pope Yeatman,	Ste. Genevieve, Mo.
W. D. Young,	Pittsburgh, Pa.

ASSOCIATES.

John H. Banks,	New York City.
Howard H. Burden,	Troy, N. Y.
Frank W. Edmunds,	Troy, N. Y.
Austin Gorham,	New York City.
Edward M. Green,	Troy, N. Y.

Henry Aug. Hunicke,	St. Louis, Mo.
Edward F. Jackson,	St. Louis, Mo.
James R. Kinealy,	Baden, Mo.
Jacob M. Rich,	New York City.
P. Williamson Roberts,	Philadelphia.
A. T. Shoemaker,	New York City.
George Thompson,	Troy, N. Y.
C. W. Tillinghast,	Troy, N. Y.
J. N. Whitman,	Pittsburgh, Pa.

The status of Mr. E. L. Herndon, in the Institute, was changed from associate to member.

The following papers were read at this session:

The Physical Properties of Coke as a Fuel for Blast Furnace Use, by John Fulton, of Johnstown, Pa.

A New Method of Manufacturing Sulphuric Acid and Sulphate of Copper, by A. F. Wendt, of New York.

These papers were read by Mr. Kirchhoff in the absence of the authors.

Notes on the Serpentine Belt in Chester County, Pa., and Supplementary Remarks on the Rocks of South Wales, by Dr. Persifor Frazer, of Philadelphia.

Boilers and Boiler Settings for Blast Furnaces, by F. W. Gordon, of Pittsburgh, Pa.

Some Canadian Iron Ores, by F. P. Dewey, of Washington, D. C.

Notes on an Experimental Working of Silver Ores by the Leaching Process, by J. H. Clemes, of Falmouth, England, read by Mr. Kirchhoff in the absence of the author.

The following translation of a letter to H. L. Bridgman, 1203 Locust Street, Des Moines, Iowa, a member of the Institute, from Bergrath von Groddeck, Director of the Royal Prussian Mining School, Clausthal, Germany, was read by the Secretary, and recommended by the President to the favorable attention of the members of the Institute.

"DEAR SIR: It is my desire to procure for the Academy as complete a collection as possible illustrative of the science of mineral veins and deposits. This collection is to serve in part in illustration of my lectures, but its principal object is to furnish material for the comparative and scientific study of this subject, which is of the highest importance to the miner, and which can hardly be satisfactorily investigated in any other way.

"The collection is to consist of specimens from as many mines as possible, such specimens being in sets, showing the various ores of the mine, any minerals it may contain, its gangue rocks, country rock, and particularly anything bearing on the genesis of the ore body, such as stalactites, pseudomorphs, druses, specimens show-

ing stratified deposit of ore, etc., etc. On the other hand specimens having simply their beauty to recommend them are of less importance.

"Whenever convenient, it is desired that specimens should be about 4 inches square; this, however, is not essential, anything with a bearing on the subject is acceptable, regardless of its form or size.

"Maps, geological and topographical, sketches, sections, written or printed data, in short anything reliable, and conveying information as to the ore-body or its surroundings, should, if possible, accompany the specimens."

Accompanying this translation was a letter from Mr. Bridgman, offering to answer any letters that might be addressed to him on the subject, and speaking of Bergrath von Groddeck as follows:

"He has, for a number of years past, devoted himself almost exclusively to the subject of ore-deposits, and is recognized in Germany as one of the few worthy followers of von Cotta. He has already accumulated a large amount of information on the subject, and is preparing matter for publication. There can be no question as to the importance of his work, and I know of no easier or surer way for our American mining men to become really acquainted with the geological side of these ore bodies, than to avail themselves of the invitation of this able investigator. He will appreciate any effort they make to assist him, and will be glad to furnish them, as promptly as possible, with any information they may ask for. Letters may be written either in German or English; and freight or express on specimens, etc., shipped to the Bergakademie, Clausthal am Hartz, Germany, will be paid there."

The following papers were then read by title:

Roasting Iron Ores, by John Birkinbine, of Philadelphia.

Differential Sampling of Coal Seams, by Dr. J. P. Kimball, of Bethlehem, Pa.

Smelting Notes from Chihuahua, Mexico, by Dr. W. Lawrence Austin, Santa Barbara, Mexico.

The Colorimetric Determination of Carbon in Steels, by A. E. Hunt, of Pittsburgh, Pa.

The followed resolutions were then introduced, and were carried with enthusiasm.

Resolved, That the heartfelt thanks of the Institute be tendered to the citizens of Troy, and to the following individuals, firms, and corporations, for their generous co-operation, and the hospitality which has rendered the present meeting at once so profitable and so delightful, viz.: The Troy Club, the Burden Iron Company, the Albany and Rensselaer Iron and Steel Company, the Hudson River Ore and Iron Company, the New York Central and Hudson River Railroad Company, and Messrs. James A. Burden, I. Townsend Burden, C. E. Kilmer, the Messrs. Gurley, Earl & Wilson, Sandford & Robinson, and Cluett & Brothers.

Resolved, That the thanks and congratulations of the Institute be expressed to the Local Committee, in view of the thoroughness and skill with which the preparation and details of this meeting have been organized and conducted, and the absolute success which has crowned every portion of the committee's plan.

President Hunt then declared the meeting adjourned.

In the evening there was a subscription dinner in Harmony Hall.

On Friday morning at 10 o'clock, the members of the Institute, and the ladies accompanying them, together with many ladies and gentlemen of Troy, took a special excursion train, kindly provided by the New York Central and Hudson River Railroad Company, to Burden Station, to inspect the property of the Hudson River Ore and Iron Company, as the guests of the company. After inspecting the three roasting kilns in process of erection, lunch was served on board the train, and then the party were conveyed in open cars, on the company's railroad, to the mines. This visit was made under the guidance of Mr. James A. Burden, President of the company.

The following members and associates were present at the meeting:

C. T. Arnberg.
William Atkins.
Richard D. Baker.
S. W. Baldwin.
P. Barnes.
James C. Bayles.
G. H. Billings.
Henry Binsse.
John Birkinbine.
J. H. Bramwell.
H. W. Bulkley.
Henry Burden.
Howard H. Burden.
I. Townsend Burden.
James A. Burden.
William F. Burden.
H. S. Church.
J. B. Church.
Townsend Church.
C. Constable.
Ralph Crocker, 3d.
Gram Curtis.
W. S. de Camp.
A. B. de Saulles.
F. P. Dewey.
John Don.
T. M. Drown.
W. F. Durfee.
T. Egleston.
J. W. Farquhar.
Walton Ferguson.
Robert Forsyth.
Persifor Frazer.
R. C. Fulton.
F. W. Gordon.
A. G. Gorham.
J. Wool Griswold.
William Gurley.
Alexander Hamilton.
G. C. Hewett.
Albert F. Hill.
Levi Holbrook.
H. M. Howe.
W. S. Hungerford.
A. E. Hunt.
R. W. Hunt.
J. E. Johnson.
E. B. Kay.
William Kemp.
C. Kirchhoff, Jr.
Edward O. Knight.
W. B. Kunhardt.
L. G. Laureau.
Nicholas Lennig.
Charles Macdonald.
J. B. Mackintosh.
John Male.
Selden E. Marvin.
W. P. Mason.
De Courcey May.
Edwin Mickley.
P. W. Moen.
E. S. Moffat.
S. F. Morris.
H. B. Nason.
F. A. Ostrander.

Samuel Peters.
W. I. Pierce.
J. C. Platt, Jr.
Addison C. Rand.
R. W. Raymond.
P. Williamson Roberts.
Percival Roberts, Jr.
C. M. Rolker.
R. P. Rothwell.
W. H. Scranton.
H. C. Shaw.
Alexander H. Sherrerd.
J. M. Sherrerd.
W. L. Saunders.
C. A. Stetefeldt.
George W. Swett.
C. W. Tillinghast.
H. G. Torrey.
W. W. Van Voorhis.
W. R. Walker.
Willard P. Ward.
Charles G. Weir.
J. N. Whitman.
J. F. Williams.
S. T. Williams.
Frank S. Witherbee.
Dr. Fr. Mor. Wolff.
F. W. Wood.
W. D. Young.

PAPERS

OF THE

TROY, NEW YORK, MEETING.

OCTOBER, 1883.

SMELTING NOTES FROM CHIHUAHUA, MEXICO.

BY W. LAWRENCE AUSTIN, PH.D., SANTA BARBARA, CHIHUAHUA, MEXICO.

In the southwest corner of the State of Chihuahua, hidden up in the foothills of the Sierra Madre, lies Santa Barbara, a small collection of adobe dwellings, which claims for itself a history dating back to the middle of the sixteenth century. For many years the mining and reduction of ores have occupied the attention of the inhabitants of this region; but of late, former activity in these pursuits appears, from some cause, to have fallen off. Like every other respectable old ruin, it is haunted by traditions of past glories, but apart from romance the engineer can find much of interest within its time-honored precincts, even if the millions represented to be hidden in its mines do not present to his technical vision the allurements others see. Occasionally the discovery of a pocket of rich ore in the vicinity awakens it from its venerable dreams, and it was such an occurrence that led the writer recently to intrude on its seclusion.

This district was of mature growth, and is lasting in its old age, differing somewhat in this respect from our Western regions. Where the American will move on in search of better things, the Mexican remains cherishing the history of bygone palmy days. The decadence of the industry here may be traced to several causes, among which are the exhaustion of the docile surface ores; the primitive methods of reduction, which do not admit of operations on an extended scale, in other words, the economical reduction of the ore; and lastly, the lack of systematic development of the mines themselves, which prevents the extraction of these low-grade ores when connected with any serious expense.

The appearance of the veins is imposing. Huge quartzose ledges, carrying zinc-blende, galena, and the various pyrites as impregnations and seams, cut through the country rock for miles, their jagged outcroppings occupying a prominent place in the landscape. They present some features which might cause a metallurgist to reflect before embarking in any scheme for their reduction. Zinc blende

predominates; iron ores are wanting, if we except the pyrites; the local supply of fuel is limited to a certain amount, too small for ambitious designs; the gangue is quartz pure and simple, and the average assay shows a very low grade of ore. Such objections may have been among the reasons why so many of these mines have lain idle these many years, so that now, upon inquiry as to who made the enormous excavations, a shrug of the shoulders, and the response "*los antiguos*," are all that can be elicited.

Some of the descendants of these mystic beings, more ambitious than their fellows, earn a livelihood by hand-sorting, or concentrating the better portion of what their ancestors left behind, preferring this to starvation, which, from all accounts, has been until now their only alternative.

The concentration is carried on in what is termed a planilla; that is, a man goes to the brook, or, rather, to a point where the brook pokes its head up through the waste of the river-bed—for, in the dry season, the current is usually hidden from view—levels off a space 4 feet by 4 feet on the bank, and paves it with flat stones, giving the whole a slight inclination toward the water. He then surrounds three sides with a wall of other flat stones, set on edge, about 12 inches high, places his fine ore in the upper end, stands off in the stream and bails the water on to the aforesaid mineral, throwing it in such a way as to cause the whole mass to be lifted by it. The lighter particles are borne away by the returning current, while those of sufficient specific gravity remain behind. In this simple apparatus the desired separation of the quartzose matter is effected quite sufficiently for smelting purposes, although there is naturally a considerable loss of the valuable minerals. The greater part of the ore smelted is hand-sorted only, obtained by following the best streaks of mineral in the mines, and selecting therefrom again the most valuable portion.

At present there are twelve blast furnaces in operation in Santa Barbara, each of one ton capacity, but eleven of these are running on ores brought from outlying mines, or other districts, and yield, in their concentrated form, 36 ounces to 66 ounces per ton. A smelter of considerable experience in this district assured me, that ores containing less than 40 ounces to the ton cannot be profitably worked, but that as soon as they reach 53 ounces they are in bonanza.

The largest works in Santa Barbara, in fact, the only ones of any consequence, are leased and operated by Mr. A. B. Sawyer,

and the following notes are mainly condensed from information furnished within those adobe walls. Here are in operation eleven shaft furnaces and four cupellation hearths, all, together with the buildings, constructed of adobes, *i. e.*, sun-dried brick. These adobes are usually 9 inches by 18 inches, and 4½ inches thick, but larger ones are used, in covering the cupellation hearths, for instance, which are 30 inches by 12 inches, and 3½ inches thick. One man can make about seventy-five of these first-named adobes in a day, and is paid 60 cents wages, so that they come to something under one cent each.

The following measures of weight and value will be given in avoirdupois pounds and United States coin. The Spanish pound does not vary enough from the American unit of the same name to make any essential difference in these calculations, and the Mexican copper currency dollar, which alone is in circulation in this district, is calculated, to avoid small fractions, as the equivalent of 80 cents United States coin, whereas in reality it is worth nearly 81 cents.

The adobes used in furnace construction are made from selected clay, of a red color, free from small stones. They can be laid in wall at about $16 per thousand. The furnaces are set in pairs, under hoods or domes, about thirty feet high, and discharge their fumes, smoke, etc., through their open tops into the working spaces. These domes require for their construction 1500 adobes, and cost about $40, independent of the price of the adobes. The furnaces are constructed by building up adobes from the floor to the height of 7 or 8 feet, leaving a rectangular shaft, inclosed on three sides, but with the fourth free. This shaft, from the top downward for four or five feet, is of small dimensions, and constitutes the shaft of the furnace; below this it widens out. When the furnace is ready for blowing-in, the fourth side of the shaft is walled up, and the enlargement below tamped solid with clay. The bottom of the shaft slopes outward and forms a basin, partially outside the furnace, in which the molten products from the furnace fall and separate. This basin or slag bath is divided by the adobes of the front wall of the shaft which dips below its surface about an inch. The shaft, when bricked in and ready for operations, has the following dimensions: 4 feet from tuyere to top, 12 inches from tuyere to surface of slag-bath, 12 inches square at tuyere and 18 inches square at top. The tuyere (2½-inch nozzle) is fitted into a copper plate (18 inches by 29 inches) which constitutes the lower back of the furnace; but usually porphyritic rock is used for this purpose. A pair of these furnaces, from

the floor up, require for their construction about 500 adobes, and two days' labor, divided as follows:

Cost of Constructing one Pair of Shaft Furnaces.

One mason at 80 cents,	$1 60	
Two helpers at 40 cents,	80	
Two boys at 20 cents,	40	
		$2 80
Tamping in crucibles:		
Six men at 40 cents, two days,		4 80
500 adobes at 1 cent,		5 00
Clay and sundries,		1 40
Total,		$14 00

This represents the total cost of a pair of furnaces, exclusive of tuyeres and copper back (which is not necessary), and divided by two, puts the cost of each singly at $7.

Operations are conducted as follows: Charges are laid out, each of 150 pounds, made up of 75 pounds of ore and 75 pounds of litharge. With these 150 pounds are charged 150 pounds slag and 45 pounds charcoal, *i.e.*, the fuel is 60 per cent. of the ore charges, rather more than less. This whole amount is not charged at once, but doled out in hatfuls to the little furnace. The mouth of the shaft is kept free from sparks. Blast is supplied at 4½-inch pressure (water) for nineteen 2½-inch nozzles, by a No. 6 Sturtevant fan. Bullion, matte, and slag flow continuously into the sumps, separating there; a crust of slag is removed as often as it chills, and the other products are tapped off as often as a new charge is begun.

Oak charcoal is used exclusively, and costs $8 per ton, pine charcoal being considered too light for the work. From 1100 to 1300 tons of charcoal are consumed in these works per annum. From another source I learn that the total consumption of charcoal in Santa Barbara mining district in 1882 was 1750 tons, which amount represented all that could be produced. This gives an insight into the amount of ore yearly beneficiated in the district. Accepting, as it is variously estimated, the fuel to represent from 60 per cent. to 65 per cent. of the ore smelted, we find this latter element covered by figures lying somewhere between 2700 tons and 3000 tons, 1000 tons of which are brought in from other districts.

Cost of Smelting one Ton of Ore.

Labor:		
2 smelters at 60 cents,	$1 20	
2 chargers at 20 cents,	40	
Laying out charges,	10	
Carrying away slag,	10	
Roustabouts,	20	
		$2 00
Fuel:		
60 per cent. of ore charge,		4 80
Total,		$6 80

This is exclusive of general expenses, blast, repairs, and superintendence.

In treating some ores ("San Francisco del Oro" mine, for instance), which carry heavy amounts of zinc-blende, a loss of 25 per cent. of the litharge charge occurs. This material is brought from a distance, and costs, laid down at the works, $42 per ton. As equal amounts of litharge and ore are charged into the furnace this loss augments the cost of smelting $10.50 per ton, which, added to the $6.80 above, brings the total up to $17.30 per ton. Probably the expenses for motive power, preparation of ore, and general outlays connected with the works, will increase these figures to $18.50, exclusive of refining, *i.e.*, when treating "black jack" ores. From data obtained at another smaller establishment, when galena ores were formerly operated upon, the total cost of smelting, per ton, summed up as follows:

Labor,	$2 80
Fuel,	5 20
Motive power,	2 00
Total,	$10 00

Both of these estimates are rather crude. The cost of repairs on furnaces is not included, neither are any of the little expenses incidental to metallurgical operations of this kind. But the main items, fuel and labor, are sufficiently near for practical purposes, and the fact is made clear, that in these little shaft furnaces, to construct which costs a merely nominal sum, very refractory sulphuretted ores are successfully smelted without preliminary roasting, at a cost of from $8 to $10 per ton. Where almost pure zinc-blende is treated, and a heavy loss in the fluxing litharge occurs, these figures are doubled. When a moderate amount of galena is present in the ore,

the litharge constantly accumulates, and is sold. A knowledge of these facts would often help our Western prospectors in developing their claims, where they now sit idly by awaiting the often tardy advent of capital. The nature of the material from which these furnaces are built does not admit of long campaigns; usually they last but ten or twelve days.

Cupellation hearths, built also of adobes, are used to refine the base bullion produced by the shaft furnaces. These are very simple in construction, requiring only a few adobes, some ashes, and clay.

Cost of Constructing one Pair of Cupellation Hearths.

Ashes for tests:		
1800 pounds for two furnaces,		$1 60
Labor used in construction:		
1 mason, one day, at 80 cents,	$0 80	
3 men, one day, at 40 cents,	1 20	2 00
Labor putting in tests:		
1 man at 80 cents,	$0 80	
3 men at 40 cents,	1 20	2 00
Clay for tests:		
600 pounds,		80
200 adobes,		1 60
Total,		$8 00

The adobes which serve as roofing are somewhat larger than the others, being 30 inches by 12 inches and 3½ inches thick. They are made from selected clay, and dried under cover so as not to show sun-cracks; they stand four weeks. The tests are made of ashes taken from the ash-pit of the furnace itself, and mixed with sifted clay, in the proportion of 3 parts (by measure) of the former to 1 part of the latter. Oak wood ashes are preferred, as they do not cut out so readily, and the tests are tamped in very firmly, wooden poles being used for this purpose. The furnace, when complete, occupies a space 5 feet wide by 5 feet high and 8 feet long, the test holding about 750 pounds of base bullion and matte. The matte, which forms in a thin cake upon the surface of the lead, when tapped from the shaft furnace, is thrown in upon the bath while refining, and runs down with it. This dissolving of the metallic oxides in the litharge constitutes the main expense of the operation, consuming much time and fuel. Six marks of silver, at 8 ounces, result from cu-

pelling 1500 pounds of a mixed charge of lead and matte, the whole operation lasting twelve hours. Oak wood is used as fuel, costing 20 cents per 200 pounds. A test of this description requires to be rebuilt every month, slight repairs being necessary after every charge.

Cost of Refining 3000 *Pounds of Lead and Matte.*

One day's run:

2 refiners at 60 cents,	$1 20
Fuel, 1800 pounds oak,	1 80
Labor,	50
Materials used in repairs,	10
Total,	$3 60

This estimate for fuel is rather low, and it might be well to add $1.20 to the above figures, so as to include surplus fuel, rebuilding, blast, and other incidental expenses. Still, then, we have the astonishingly low result of $4.80 for 3000 pounds, or $3.20 per ton. The loss in lead during this operation amounts to 11 per cent. The silver obtained is melted down in a furnace similar to those used throughout our Western country for a like purpose, but built of adobes. In the place of costly graphite crucibles, old quicksilver flasks are made use of in this melting, a flask lasting for fifteen to twenty bars, according to the strength of the welding. The bars are not allowed to contain over 1080 ounces, and by using two flasks and one furnace twenty can be cast in one day. Pine coal is used in the melting furnace. The bar silver runs from .970 to .980 fine.

The ore, heavy in zinc, is partially roasted in kilns at the mines before being brought to the smelters. These kilns are 10 feet high, 12 feet long, and 4 feet broad. On the bottom are two air canals, covered with pieces of strap-iron set on edge, which act as grate-bars. On these wood is piled a foot high, which, in turn, is covered with ore, about 15 tons, until the kiln is two-thirds full. One other layer of wood having been thrown in about the middle of the charge the front of the kiln is sealed up and the charge fired. The exit for the fumes is quite small, in order to limit the access of air from below. The ore loses about 10 per. cent of its weight during this operation, which is represented to cost 22 cents per ton. The oak wood used is approximately 2 per cent. to 4 per cent. of weight of the ore charged, and costs $2.20 per cord.

The entire cost of the roasting, smelting, and refining operations

to which this rebellious ore is subjected, sums up to, approximately, $20 per ton, the product being bar silver, .980 fine.

The system is characterized by two features,—the small quantity of material it is possible to operate upon, and the consequent waste of time; it has, therefore, little to recommend it, except for operations on an experimental scale. It owes its success mainly to cheap fuel and labor, but both of these commodities are limited, and prevent extended operations. Lead is sacrificed because of the absence of iron; still, when we consider the quality of the material treated, the small amount of lead ore mixed with zinc-blende and antimonial and arsenical compounds, the result is very creditable.

At one small works I found them working the blast by man power, the whole concern being of home manufacture, bellows, furnace, and all!

I am indebted to Messrs. Beckman & Storck, of Santa Barbara, for much of the metallurgical information contained in the above.

SOME CANADIAN IRON ORES.

BY FRED. P. DEWEY, WASHINGTON, D. C.

THE iron ores of Canada have attracted more or less attention in this country for a number of years; and having had an opportunity this past summer to examine some of them, especially the magnetic ores, I have thought it might be of sufficient interest to the members of the Institute to put on record some of my observations.

The region examined contains, for the most part, only the rocks of the Laurentian system. Much of it was originally covered with a dense growth of pine, which interfered with successful prospecting for ores. However, after the best of the timber had been cut off, fire generally got into the bush and cleared it up pretty well. This, besides making travelling about easier, exposed large surfaces of rock, and rendered the work of the prospector far more liable to be rewarded with success, while removing many of its hardships. The general appearance and productiveness of the land have, however, been far from improved by this process. It would be difficult to find a more desolate-appearing country than some of these pine woods after fire has been through them.

The country examined may be, for convenience, divided into two

sections: the one in Ottawa and Pontiac counties, in the province of Quebec, beginning at the Haycock location, northwest of Ottawa, and continuing up the Ottawa River to the Ade location, in the township of Bristol; and the other south of the Ottawa River, and east of the Kingston and Pembroke Railway, in the counties of Lanark, Leeds, and Frontenac, in the province of Ontario.

The Haycock Mine.

This mine is located in the northeast portion of the township of Templeton, about eight miles east of the Gatteneau River, and about twelve miles from the City of Ottawa. The occurrence of the ore is very remarkable. The ore consists of hematite, with a considerable amount of magnetite, and is remarkably pure. It is very hard and compact, showing, in some cases, distinct cleavage; but most of it occurs in lumps, from the size of a walnut up to a few cubic yards, scattered through the rock, which is a very coarsely crystalline aggregate of a pinkish felspar and quartz, with rarely a small amount of hornblende, and mostly in association with the felspar. One especially curious feature was aptly described by my guide, who said, "It looked as if a ladleful of molten ore had been dashed down upon the surface of the rock." There is more or less apparent parallelism in the occurrence of the ore-bodies, but there were few indications of a well defined and permanent deposit.

There was one good-sized opening, besides a number of small pits, from which perhaps 2000 tons of ore had been extracted; but the mining must have been rather expensive, and from the small and isolated nature of the ore-bodies must be very uncertain. Notwithstanding this, a forge of four fires had been built in which some very good blooms were made, and four large charcoal kilns had been built, also a tramway to the old furnace at Hull. All these works, however, have been out of use for several years, and are rapidly going to decay. The composition of the ore in selected samples is given by the following analyses from the *Canadian Geological Survey.**

Fe_2O_3,	88.08	89.80	85.45
FeO,	6.86	7.06	5.24
MnO,	0.24	trace	0.15
CaO,	0.55	trace	0.41
MgO,	0.13	0.22	0.17
P_2O_5,	0.16	trace	0.13

* 22d Rep. of Prog. Can. Geol. Sur., 1873–74, p. 226.

S,	0.03	trace	0.07
TiO_2,	3.17	2 34	2.12
C,	0.35	0.43	0.28
Insoluble,	0.26	0.11	5.77
	99.83	99.96	99.79
Fe,	66 98	68.34	63.88

Analyst, Professor E. J. Chapman.

The Hull Mines.

Iron ore has been mined at Hull, Quebec, with varying degrees of activity, for more than twenty-five years, the product having been between sixty and seventy thousand tons. At the time of my visit work had been temporarily suspended, awaiting the completion of the Gatteneau River Railway, which will pass within a short distance of the Forsythe mine, so that the principal shaft was full of water, and no direct observations could be made underground. The ore occurred in a series of outcrops in a general east and west direction. Many of these outcrops were small, and had been worked out after having produced a few hundred tons of ore. The principal mine, the Forsythe or Old Ironsides, has produced about 60,000 tons, and is said to have considerable ore yet in sight in the lower workings. On the surface it showed a width of 15 to 35 feet in a cut 100 feet long. The occurrence of the ore here is also peculiar, being entirely in a very impure limestone, the latter being associated with a hornblendic gneiss. The limestone is white and crystalline, and the principal impurities, which form a considerable portion of the whole mass, are a light green pyroxene, quartz and graphite. The ore is of two kinds, the black magnetite ore and the so-called red ore, which is a mixture of magnetite and hematite. It is hard and compact, with imperfect cleavage, and generally shows a considerable number of flakes of graphite on a fresh fracture. Cavities showing well-crystallized calcite are also common. This ore, besides being shipped to the United States, was smelted in the old charcoal furnaces at Hull* (size 38 by 10½), and produced some excellent iron. The composition of the charge was very poorly calculated, for besides limestone, considerable amounts of clay and siliceous sand were used, which were entirely unnecessary, not only decreasing the capacity of the furnaces, but also increasing the consumption of charcoal, which was excessive, being 235 bushels per ton. The following analyses were taken from the *Canadian Geological Survey Report*.†

* Dr. T. S. Hunt, 18th Rep. of Prog. of Can. Geol. Sur., 1866–67.

† 22d Rep. of Prog. Can. Geol. Sur., 1873–74, p. 211.

	Red Ore I	Black Ore. II.	Black Ore (picked specimens). III.
Fe_2O_3,	66.20	73.90	93.82
FeO,	17.78		
Mn,	trace	none	0.12
Al_2O_3,	....	0.61	0 79
CaO,	1.85	....	0 45
MgO,	0.18	1.88	0.94
P,	0.015	0.027	0.08
S,	0.28	0.085	0.11
CO_2,	1.17	....	....
SiO_2,	11.11	20.27	3.75
TiO_2,	none	none	....
Graphite,	0.71	....	....
H_2O,	....	3 27	....
	99 295	100.042	100.06
Fe,	60.17	53.51	67.94
Analysts,	Dr. T. S. Hunt.	Dr. T. S. Hunt.	Prof. C. F. Chandler.

Bristol Mines.

Following up the Ottawa River from the Hull mines there are several occurrences of iron ore, but we find little development until we come to Bristol. In this township, on the farm of Charles Ade and the adjoining farm, there are several good outcrops of ore, and the magnetic attraction is very strong over a considerable area. The relationship between the outcrops is somewhat complicated, and more work is needed to establish it clearly. About ten years ago two openings were made from which perhaps 3000 tons of material were taken. The ore-body, which occurs in a fine-grained hornblendic gneiss, at times very coarsely crystalline, is made up of tough black hornblendic rock, with very pure ore scattered through it. The ore is fine-grained and granular, and rich in iron. Much of it has a fine blue tarnish from exposure ; it contains numerous seams and bunches of cupriferous iron pyrite, making it quite high in both sulphur and copper. It also contains considerable disseminated light-colored hornblende, and an occasional seam of calcite. This mine is at present too far from transportation to be worked profitably; but a projected railway will run within a short distance of it. The ore is of the following composition :*

Fe_2O_3,	65.44
FeO,	14.50
FeS_2,	2.74

* 22d Rep. of Prog. Can. Geol. Sur., 1873-74, p. 208.

MnO,	0.11
Al_2O_3,	0.60
CaO,	3.90
MgO,	0.45
SiO_2,	11 45
CO_2,	1.64
P_2O_5,	traces
TiO_2,	none
H_2O,	0.14
	100.97
Fe,	58 37
S,	1.46

Analyst, Dr. B. J. Harrington.

Localities South of the Ottawa River.

Of these localities a division can be made into two classes; the openings which were made about ten years ago, and upon which there has been no recent work, all of them at some distance from the Kingston and Pembroke Railway; and the mines in active operation directly on the line of the railway. The former were made upon the outcrops of small bodies of ore, and were worked crudely and intermittently. The ore was generally mined and taken away in winter, when hauling is cheap. In several cases a few hundred tons of ore exhausted the opening, and a new one was started close by, but in no place were there any indications of a large or permanent deposit of ore, and in no case was the mining carried to any great depth. The openings on the shores of Christie's Lake, in South Sherbrooke, offer a most desirable location for large and active mining operations, being on a considerable cliff with steep sides, affording easy access and abundant dumping-ground. But the amount of ore seems to be limited; and the locality is chiefly interesting for the variety of minerals thrown out, amongst which may be mentioned pyroxene, scapolite, sphene, a pink calcite, and an occasional crystal of apatite. The rock is a hornblendic gneiss of a curiously banded structure, due to the accumulation of hornblende in certain narrow layers. The ore is coarsely crystallized, coarse octahedrons being quite common, or compactly massive, with octahedral cleavage, well developed, and is of the following composition:*

Fe_3O_4,	90.61
TiO_2,	2.83
P_2O_5,	0.05
Fe,	65.62

Analyst, Dr. B. J. Harrington.

* 22d Rep. of Progress Can. Geol. Sur., 1873-74, p. 210.

From the Fournier openings in South Sherbrooke a considerable amount of ore has been taken, one of the openings being 100 feet deep. The ore-body is in the same hornblendic gneiss, and consists of tough hornblende rock with the ore, which is very hard and compact, showing indistinct cleavage and an occasional seam of pyrite. The percentage of iron, as determined by Dr. Harrington, is 59.55.

From the Bygrove mine, also in South Sherbrooke, at the foot of Bob's Lake, a considerable amount of interesting mineralogical material was taken, but the ore appeared to be scattered in small veins through the rock, the whole mass not being very rich. Among the minerals observed may be mentioned hornblende, pyroxene, scapolite, pink calcite, and cupriferous pyrite. The percentage of iron, as determined by Dr. Harrington, is 59.59.

On the very edge of Spectacle Lake, in North Crosby, near Westport, an opening 12 feet deep had been made. From this a considerable amount of a fair ore containing cupriferous pyrite had been taken, and from an adjoining lot more of the same kind had been extracted.

The mines in active operation are in the immediate vicinity of the Kingston and Pembroke Railway. There is great similarity in the occurrence of the ore; and a few words, by way of general introduction, will apply to all.

The ores in general are fine-grained, hard, and compact; consist of magnetite in intimate association with more or less hornblendic and chloritic material, and frequently show a banded appearance. They also contain considerable calcite and dolomite, finely disseminated and in bunches. The only apparent difference in different localities is the presence of more pyrite in some than in others.

The veins vary in thickness from a few feet up to 40, with a general northeast and southwest strike, and a 25 to 40 degrees dip to the southeast. The walls are very persistent, being the same with one exception in every case, the formation being the Laurentian. The foot-wall is a white, moderately crystalline limestone, with a considerable percentage of magnesia; it also contains considerable white, crystalline, glassy quartz; a silver-white mica, and an occasional speck of graphite. It is very uneven, rising and falling frequently, with a wavy surface, which accounts for much of the variation in the thickness of the veins.

The hanging-wall presents many variations in texture, tint, and the ratio of its different constituents, but it is always a reddish or dark hornblendic gneiss. It varies in texture from a coarsely crys-

talline rock, in which the different minerals can be readily distinguished macroscopically, and in which an occasional seam shows well-formed crystals, to a very fine-grained and compact rock. The prevailing color is red, but there are many shades; and some of the very fine-grained specimens, especially those containing considerable hornblende, are dark, sometimes almost black. The proportion of hornblende varies from an occasional flake in the coarse and very red varieties to a considerable amount in the fine-grained and dark varieties. The visible accessory minerals are epidote, and an occasional speck of pyrite. It is a moderately strong and tenacious rock, and, when undisturbed, in the finer-grained varieties, especially, makes a fairly good roof.

The Calabogie Lake Mines.

The northernmost openings of this series are near Calabogie Lake, in the township of Blithefield. Beginning at the opening farthest from the lake, the Calabogie Iron Company had gone down about 40 feet, and were preparing to put up hoisting machinery. The strata are decomposed to a considerable depth, and are very much disturbed from a cross-dyke, and the work had not progressed far enough to make out the relationships exactly. The ore presents a variety of aspects, being also influenced by the cross-dyke. Some of it is fine-grained and granular, some compact, some showing a banded structure. As mined it will average about 50 per cent. of iron, and contains considerable calcite, and also some cupriferous pyrite.

The same company has another small opening on the land of Mr. Thomas Church, from which a small amount of material had been taken and then the work stopped.

Between these two openings Mr. Coe had just commenced work on a vein showing about eight feet of ore at the surface, with a dip of about 30 degrees. The ore is very hard and compact with some traces of cleavage. It contains some pyrite and calcite (both crystallized, and a pink cleavable variety), and also some amethyst.

The fourth and last opening has been made by the Calabogie Iron Company on the very shores of the lake, in Grassy Cove. This opening shows a well-defined vein with both walls, and was down about 60 feet upon the dip, which is about 25 degrees towards the south, the strike here approaching east and west. About 2000 tons of ore had been taken out and boated across Grassy Cove to the railway, which will not be finished across the cove for some time on

account of a heavy fill. The ore is fine-grained and granular, much of it being very distinctly stratified, and some of the strata being cupriferous pyrite, of which the ore carries a considerable amount. Among the associated minerals may be especially mentioned the occurrence of prehnite in curious worm-like forms, showing a stellate arrangement of imperfect crystals upon a cross-fracture. The following analyses represent the composition of the various ores from the openings of the Calabogie Iron Company. I am indebted for them to Mr. Edward Elliott, President of the Calabogie Iron Company, of Perth, Ontario:

No. 1.—Near Lake.

Fe_2O_3,	44.59	....	....	....	....
FeO,	35.83	....	....	....	....
SiO_2,	4.28	5.53	4.44	3.24	....
TiO_2,	0.60	....	....	....	....
P,	0.028	0.012	0.018	0.025	0.18
S,	·0 38	....	....	....	....
Fe,	59.76	61.48	65.15	62.23	63.619
Analysts,	Mr. Emerton.	Mr. Charles E. Wright.			Dr. Fricke.

No. 2.—Church's Lot.

Fe,	52.326
P,	0.190

Analyst, Dr. Fricke.

No. 3.—Farthest from Lake.

Fe_2O_3,	58.98	....
FeO,	22.35	....
SiO_2,	4 35	....
TiO_2,	0.40	....
P,	0:203	0.143
S,	0.10	63.62
Fe,	58.67	....
Analysts,	Mr. Emerton.	Dr. Fricke.

The Raddenhurst & Sherritt and W. C. Caldwell Mines.

About twelve miles south of the Calabogie Lake mines is the Raddenhurst & Sherritt mine, near Round Lake. The main shaft was down about 68 feet, showing the same walls, and northeast and southwest strike, but with only a very small dip, not over ten degrees to the southeast. The hanging-wall here was the darkest observed anywhere. Some of the smaller openings seemed to indicate

the presence of a cross-vein, but its existence was not fully established. Most of the ore is compact and stratified, some of the strata being a cupriferous pyrite, which forms a considerable percentage of the ore; and it is very prone to decompose, so much so that upon exposure for a short time to the atmosphere many lumps crumble to a coarse powder. Some of the ore is compact, crystalline, and cleavable, and contains dolomite scattered through it.

About one-half a mile south of this Mr. W. C. Caldwell had put down a shaft which was idle and full of water. The ore and general appearance seemed to be the same as the foregoing.

The Bethlehem and B. Caldwell Mines.

About twelve miles south of the last location, in the township of Levant, is the scene of the most active mining operations of the whole region. The presence of magnetite at this point has been known for many years, from the difficulty experienced in the use of the compass by the land-surveyor when the country was first plotted. This fact being known to Mr. Boyd Caldwell, an extensive lumber dealer, he not only purchased the timber from the government, but also took out a patent for the land. The question of the ore remained dormant, however, for many years, on account of the inaccessibility of the country, until there was a prospect of rail-communication by the construction of the Kingston and Pembroke Railway. Work upon the development of the ore was first undertaken by Mr. Caldwell in January, 1880, and carried forward until the presence of a large body of ore was clearly established, when, in July, 1881, a portion of the land was leased to the Bethlehem Iron Company, which has carried on active mining operations ever since. At the time of my visit about seventy men were employed in the principal mine, which was down about 250 feet, the product being 100 tons per day of a good 50 per cent. Bessemer ore, the total product having been about 30,000 tons.

On the adjoining lot, Mr. Caldwell was working one drill and a small force of men upon the same vein. He has gone down 200 feet; but his work is entirely developmental, and he has not attempted to carry on regular mining operations.

The general characters of the vein, as exhibited in both shafts, are the same. The vein strikes northeast and southwest, approaching, however, to the north, and dips 30 to 35 degrees to the southeast. The walls are very persistent, with well-defined selvedges. The thickness of the vein varies from two to thirty-one feet, due

principally to the rolling of the limestone foot-wall, which is excessive. The ore is compact, crystalline, and cleavable magnetite, mixed with a large amount of chloritic material, which occasionally, although not always, gives a stratified appearance to the ore. There is very little visible pyrite in the ore, but it contains a considerable amount of carbonates of the alkaline earths, varying in composition from a nearly pure calcite through a true dolomite to magnesite, containing a considerable percentage of carbonate of lime. The dolomite sometimes occurs in large masses, near which the ore is generally very much richer, as if the dolomite ordinarily scattered through the ore had been gathered into one mass by itself, which would necessarily enrich the ore from which it had been withdrawn, while some of the calcite occurs in small veins, with a beautifully fibrous structure.

Among the minerals at this locality may be especially mentioned a coarse, gray asbestos and a green chlorite in good-sized cleavable foliæ.

The ore is shipped to the works of the company, at Bethlehem, Pennsylvania, and the composition is represented by the following analyses:

Fe,	63.730		58.49	Fe_3O_4,	89.04
SiO_2,	4.466		9.15 (rock matter)		6.34
TiO_2,	....		....		...
CO_2,	....		....		1.97
Al_2O_3,	....		0 28		0.38
Mn,	....		1.79		trace
CaO,	....		3.32		1.15
MgO,	....		5 66		1.06
P,	0.028	P_2O_5,	0 071		traces
S,	0.032		0.12	SO_3,	traces
Analysts,	Rhodes & Co.		Mr. E. M. Reed.		Prof. E. J. Chapman.

The Roberts Mines.

About ten miles south of the last mines, in the township of Palmerston, are the Roberts mines. The ore occurs here in isolated lenses, and the mining has been very uncertain. At the time of my visit the ground was being very thoroughly prospected with a diamond drill in the hope of removing at least a part of the uncertainty, and some very good-looking cores had been obtained. The use of the needle here is very deceptive, as the rocks are full of small veins and strings of magnetite, which give strong attractions over a wide surface. The principal shaft, the Lizzie, had gone down 180 feet on the dip, and produced about 60,000 tons of excellent

ore; but at this point the ore had been sharply and completely cut off. The method of this cutting-off was peculiar, and I had not sufficient time to explore it thoroughly; the rock beyond is the hanging-wall, but with a large increase in the amount of hornblende, with the size of the particles of each mineral approaching uniformity. This would lead to the supposition that the worked-out ore-body had risen upward as the result of a fault; but if so, it was a peculiar fault, since all signs of violent disturbance at the juncture of the ore and rock are wanting: The line of demarcation between the two is very distinct, but the continuity is scarcely broken.

Another explanation of the phenomena may be that the deposit of ore was a pocket in the rock and had been worked out, but it had well-defined and regular walls similar to the other veins, a limestone foot-wall and hornblendic gneiss hanging-wall, also the regular dip and strike of the other veins. It would be necessary to spend considerable time, and probably considerable more mining would have to be done, to thoroughly work out the causes of this cut-off.

The ore was coarsely crystalline, cleavable, and rich. There was but little visible pyrite; but associated with the ore was a handsome pink crystalline calcite, carrying cupriferous pyrite; the hanging-wall at this point showed a large amount of epidote and also graduated at times into a typical gray gneiss.

From the Mary shaft, just north of the Lizzie, about 20,000 tons of a fine-grained granular ore, very different from the Lizzie ore, had been taken out to the depth of 40 feet, and then mining was suspended.

Besides the above principal openings, several prospecting openings were being developed to ascertain what the surface shows, which in some cases were very good, would lead to. Although the full working force was 80 men, only 20 were at work with the diamond drill and performing the prospecting work. The ore was shipped to Elmira and Charlotte for smelting, and its composition is shown by the following analyses, for which I am indebted to Mr. B. W. Folger, of Kingston, Ontario:

Fe,	57.77	63.2
O,	....	24.7
SiO_2,	15.10	6.8
Al_2O_3,	0.29	undetermined
CaO,	6.38	1.8
MgO,	2.47	....
Mn,	0 40	traces
P_2O_5,	0.025	....

S,	0.08	0.2
CO_2,	....	1.5
TiO_2,	....	trace
Analysts,	Mr. E. M. Reed.	Mr. J. B. Britton.

The Glendower Mines.

The last mines of which I shall speak are the Glendower mines, about four miles from Bedford Station, and twenty-one miles south of the Roberts mines, on the shore of Thirty Island Lake. An opening very near the lake presents the single exception mentioned in regard to the walls. An upthrow here has apparently transposed the limestone foot-wall into the hanging-wall. There is also cutting across the ore a small dyke, eight inches thick, of typical gray gneiss. The shaft, which was down about 100 feet, was following along this cross-dyke. Work was begun in May, 1883, and sufficient work had not been done to fully settle the relationships. About 4000 tons of ore had been extracted. It is very hard, compact, and cleavable. Associated with the ore, both in small veins, and in bunches, is a variety of carbonates of the alkaline earths, varying in composition as at the Bethlehem mines; but the analyses showed, in some cases, such an excess of magnesia as to indicate that a considerable amount of magnesite must be mixed with some of the dolomite, although every one of six specimens of the carbonates which I examined showed an amount of lime sufficient to be precipitated by sulphuric acid in moderately concentrated solutions. In one case the carbonate was undergoing decomposition into a silicated material looking a little like serpentine. Occurring in a very similar manner to the carbonates is a white cleavable felspar. Serpentine is quite abundant in some portions of the ore, and there is also some visible pyrite.

To the west of this opening, a second shaft was being sunk, which, after passing through about 90 feet of a mixture of hornblendic material, and magnetite too low in iron to be considered available ore, passed through about 12 inches of a cleavable calcite, carrying pyrite, chalcopyrite, and mispickel in large amounts. After passing through this layer, good, hard, and cleavable ore like that in the other shaft had been found, and at the time of my visit they were about 20 feet in it without any change.

About 2000 tons of the ore have been shipped to Zanesville, Ohio, the composition of which is represented by the following analyses, for which I am indebted to Mr. B. W. Folger, of Kingston, Ontario.

Fe, . .	62.32	63.80	60.96	63.01	64 89	61.39
SiO_2, .	10.67	8.30	7.27	9.04	6.26	6.61
Mn, . .	0.51	0 47	0 80	0.61	0.48	0.61
Al_2O_3, .	....	....	0.50	0.62	0.55	0 75
S, . .	0.39	0.12	0.071	0.42	0 22	0 23
TiO_2, .	....	....	traces	trace	trace	trace
CaO, .	0.64	0.09	1.86	0.54	0 48	0 50
MgO, .	0.98	4.01	3.88	4.49	2.04	5.29
P, . .	0.01	0.011	0.012	0 020	0.013	0.012
Analyst,	E. M. Reed, June 14,'83.	E. M. Reed, June 25,'83	E. M. Reed, Oct. 9,'82.	E. M Reed, Nov. 1,'82.		

BOILERS AND BOILER-SETTINGS FOR BLAST-FURNACES.

BY F. W. GORDON, PITTSBURGH, PA.

SINCE the waste gases of the blast-furnace came to be generally utilized in heating the blast and raising steam, the gradual improvement in the economy of fuel, mainly through the use of higher temperature in the blast, has impoverished the gases. The increased output per unit of measurement of the furnace, and the increased height of the furnace, have markedly increased the resistance to the blast, thus enormously increasing the duty required from the gases.

In other words, a gas reduced in heating power by a further dilution of CO_2 is required to raise the temperature of the blast to 1800° Fahr., where formerly 600° was a good temperature, and at the same time to raise steam enough to drive the air into the furnace at a pressure of from four to eight pounds in coke practice, and from eight to twelve pounds in anthracite practice, and also pump at least double the water formerly used at furnaces.

Hence the necessity for the employment of the best scheme for thoroughly consuming these gases with the least dilution of air, and the use of the best device for absorbing the heat produced for the purposes above mentioned.

In a former paper before this Society the writer called attention to such improvements as had been made by his firm, by which it was claimed 1400° Fahr. could be maintained in the blast by a less consumption of gas than was required to maintain 900° when using pipe-ovens; and it would not be too much to say that 1600° Fahr. might now be written in place of the 1400°.

The object of this paper is to give the practice of our firm in the

raising of steam by the waste gases, and our reasons therefor. We are certain the gases at present passing from our blast-furnaces are ample for all purposes.

Furnaces are variously proportioned in the matter of the heating surface of their boilers. Some engineers figure from the cubical measurement of the furnaces, others from the diameter of the bosh, and others on the make of iron. The latter basis we adopt for calculation, since the fuel-consumption is fairly near in proportion to the iron-product, and the air required nearly in proportion to the fuel used. Our experience represents approximately the product and fuel-consumption for a given fuel and ore.

Anthracite furnaces now in use have from 60 to 110 square feet of heating surface in their boilers per ton of iron per twenty-four hours; coke furnaces range from 40 to 80, and charcoal furnaces from 20 to 50 square feet. It is apparent that, in determining their proportions, no settled basis of calculation has been used by constructors.

In the spring of 1880 our firm was called upon to remodel one of the furnaces of the Isabella plant at Pittsburgh, Pa. We found these two furnaces making from 500 to 550 tons of iron per week, each with a large consumption of fuel per ton of iron. Steam was furnished by twelve plain cylindrical boilers, each 42 inches in diameter and 60 feet long; burners being placed above the grate bars, a great space under the boilers from the bridge-wall back, and four firemen per shift heaving coal under them.

As we proposed to make 1400 tons per week with the remodelled furnace, leaving the other at 500 tons, or a total make to the plant of 1900 tons per week, and as the fuel-reduction in the remodelled furnace was expected to be at least 25 per cent., and the increase of pressure of blast, due to the enormously increased volume passing through about the same column of material, was estimated at 40 per cent., the steaming capacity of the plant was a subject of much solicitude.

We proposed, therefore, that one battery, consisting of two boilers of the twelve referred to, should be changed to the plan shown in Figs. 1 and 2, to determine what increased efficiency might thereby be gained. This experiment would also determine the setting of the new boilers about to be erected. The result of the change was so marked in the increased quantity of water evaporated in the altered battery, that the entire old plant was ordered to be changed at once, after which the former heavy firing was discontinued en-

tirely, all necessary steam being raised with the furnace-gases alone. The twelve boilers were then steaming for a product of 1000 tons per week, or 145 tons per day, representing thirty feet of boiler surface

Fig. 3.

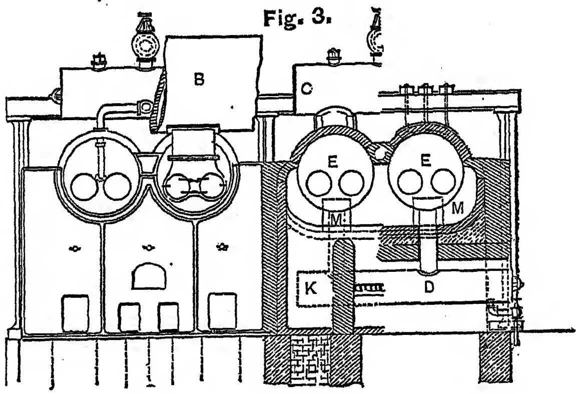


Fig. 4.

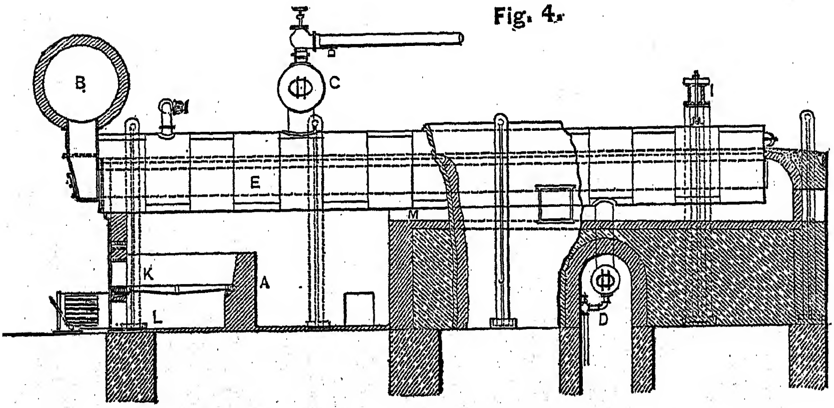
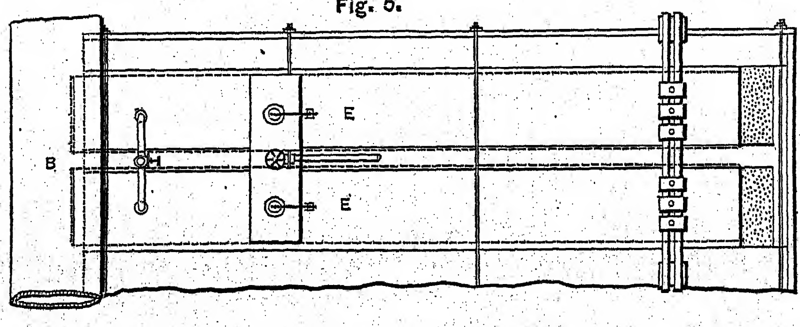


Fig. 5.



per ton of iron in twenty-four hours, everything else (except the new setting and the discontinued heavy firing with solid fuel) being as it had been before. The blowing-engines were of the ordinary upright

pattern with slide-valves on the steam-cylinders, and without auxiliary cut-off of any kind.

During the remodelling there were erected four batteries of two each of the double flue type, as seen in Figs. 3, 4, and 5. These were 46 inches in diameter and 34 feet long, the flues being 16 inches in diameter. Each of these boilers has a total heating surface of 500 feet, but as flue-surface is not worth for steam-raising more than one-half as much as overhead shell-surface, these boilers should not be estimated, when contrasting them with ordinarily constructed plain cylindrical boilers, at more than 354 square feet each. We had, therefore, twelve cylindrical boilers, each with 336 feet of heating-surface, and eight flue boilers, each with 354 feet of heating-surface, or a total of 6864 square feet for the entire plant. With this a product was obtained of more than 1900 tons per week without firing the boilers, representing nearly twenty-five square feet of heating-surface to the ton of iron in twenty-four hours. On test, however, the steam was raised with two of these boilers off. The pumps used were of the ordinary type of long-stroke Cameron, no compounding or condensing being employed in any case. The consumption of water was about 50,000 gallons per hour, and necessarily much steam was consumed in raising it.

The same double-flue boiler and setting is used at the Cleveland Rolling-Mill Company's new furnace, where, on a test for six hours, 23,000 cubic feet of blast was propelled into the furnace, all pumps kept in use and hoist full at work, with ten boilers of this size, representing a heating-surface of about 3540 square feet. The work done during this test was fully up to 200 tons per day, or at the rate of only 18 square feet of surface per ton of iron in twenty-four hours.

We have used these burners and this setting under ninety-seven boilers, raising steam for furnaces using all kinds of fuel and ores, and we think it good.

Figs. 6 and 7 exhibit this plan as proposed and used for double boilers; and Figs. 8 and 9 show the old-style of setting.

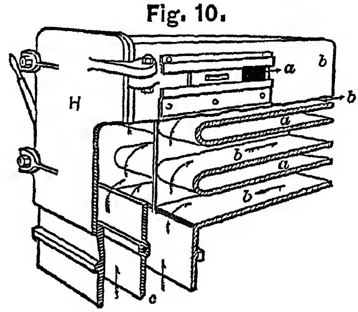
The burner (Fig. 10) has the following dimensions:

The gas-channels, *b*, are $2\frac{1}{2} \times 16$ inches in cross-section. There are four of them, giving a total area for the gas of 160 square inches to each boiler. There are, alternately with these, three air-channels, *a*, which are 2×16 inches; total area for air to each boiler, 96 square inches. The air enters to these three channels through three ports on each side of the burner, the port-area being equal to the channel-area. Over these ports there are slides to regulate the air-supply. The butterfly, *c*, regulates the flow of gas.

Experience has shown that the amount of air entering through this ninety-six inches is about the amount required to oxidize all the gas that the chamber and flue will take. Or, in other words, when the boiler is working to full capacity, the air-ports are drawn wide open, and the butterfly-valve is used to regulate the gas-supply. The proper quantity of gas is almost exactly determined by the color shown in combustion; the plan being to put in too much gas and gradually close the butterfly till all gas-burning color is lost in the flame under the boilers. Adjustment is then correct till the altered flow of gas disturbs the proportions, a change which is ordinarily not sufficient to materially affect the steam.

The objects sought in designing this boiler gas-burner were great surface contact of the gas and air and ready cleaning of the gas-ports.

Fig. 10.



By opening the door, H, a scraper can be pushed through the gas-channels, and the burner fully cleaned in two minutes. The gas-passages are made larger than necessary when clean, to allow for some collection of flue-dirt.

In designing the setting, it was thought most desirable that the gas and air should be introduced, as above, thoroughly mixed, as far from the cooling action of the boiler as was consistent with reasonable construction (see *L*, Fig. 4). The combustion-chamber, soon reaching a high heat, greatly facilitates the combination of the CO with the O of the atmosphere. The combustion-chamber was made some 15 feet long, to allow for the rapid expansion of the gases due to heat; practically to complete the combustion; and, during the expansion, to deposit a large proportion of dirt. The gases, in passing from this chamber, are brought in direct contact with the boiler-shell by reducing the passage as much as possible consistent with good draught, at the same time providing a passage (*M*, Figs. 3 and 4) as nearly of the same area as practicable, that all the surface may be equally utilized.

In setting boilers of the double or French type, or the ordinary cylindrical boilers, care is observed that the ports (*N*, Figs. 6 and 7) entering the draught-flue are so designed that the gases will hug the surfaces as much as possible. To effect this, the boilers at the chimney-end do not pass through the wall, but are terminated 12 to 18 inches short of it (see *O*, Fig. 7), the ports being placed directly on the end of the boilers so that the gases' most direct line is along the boilers' surface and round their ends.

The double-flue type was adopted for the following reasons: a gas passage could be obtained 68 feet long without using long boilers; and there is less cost in boilers, foundations, and settings for a given efficiency. Two supports only are used, one being on the front while the back end is swung from two amply strong I beams, thus giving free play to the changing form of the boiler. Moreover, in considering the safety of boilers, this type of double-flued boilers seemed to meet the requirements that promote safety more than any form that is used in furnace-practice, for the following reasons.

1. They are good circulators, the water passing rapidly up next the shell and down between the flues.

2. They are not subject to the severe "hogging" of long boilers, which, whether on springs or on rocking levers, must soon weaken their circular seams at the bottom. Nothing is more common in boiler repairs than patching these very seams. Weakening at this point is a fruitful source of explosions. In proof of this, in the four boiler-explosions that the writer has personally studied, the boilers flew apart endwise, not bursting longitudinally in any instance. Yet it is fully established that the circular seams have double the strength of the horizontal seams when the boilers are new.

3. Short boilers with flues are not so subject as long open vessels of the cylindrical type, to the wave-action of the water, which is considered also a fruitful cause of explosions.

Each battery of two boilers is provided with a good-sized cross steam-drum, with large connecting legs, that the water may be maintained at an equal level throughout. Each boiler is fed on top, the feed water being introduced in small streams through a long perforated pipe, forbidding any contact of the feed water and heated shell, the mud-drum being used for deposit collection only.

The defects of the ordinary settings are supposed to be, first, in introducing the gases. The burners ordinarily used, are supplied with from three to four 4-inch air-tubes for two boilers, or an area, at the most, of 50 square inches, the remainder of the air being intro-

duced through the grate-bars or side-doors, where it would not properly intermingle with the gas. Besides this, combustion has to be effected in close proximity to a boiler-shell, with a temperature not exceeding 350° Fahr. in ordinary practice, where, with cold air, proper combustion could not be effected. Hence the necessity of a good space under the boilers, back of the bridge-wall, where the combustion is sought to be effected. But as the gas and the air have partly combined, and lost much of their initial energy, and have given off considerable heat, the further combustion has to be assisted by firing the boilers and giving them heat. The burners, besides, being badly proportioned and wrongly placed, are exceedingly awkward to clean.

Figures 6 and 7 show an improved type of ordinary boiler-setting, in which the outgoing gases pass into the flue which is below the boiler, causing the current to run low, and not impinge properly on the entire surface of the boilers. This is a very common plan of setting.

Though we have set ninety-seven boilers according to our plan, since the spring of 1881, we never have had a failure to raise all necessary steam, except in one instance, where ores low in silica and high in alumina were attempted to be fluxed with lime. The gases in this case were so smoky that the boilers, at times, could not be seen through them, and a coating, largely of alumina, one-half inch thick, formed on the shells and flues every twenty-four hours. To add to these troubles, the feed-water was so bad that ¼-inch perforations of the feed-pipe, closed in the face of the pressure of the feed-pump, in a short time. More recently, however, more silica and less lime is used at this place, and a good supply of steam is now obtained. We have, therefore, not a single case where boilers, set as in the proposed plan, fail to furnish all steam required for good non-condensing machinery with furnace-gas alone as fuel.

Our recommendation for proportioning boilers when set in the manner here proposed is, for coke practice, 30 square feet of heating surface per ton of iron per 24 hours, which the furnace is expected to make, calculating the heating surface thus: For double-flued boilers, all shell-surface exposed to the gases, and half the flue-surface; for the French type, all the exposed surface of the upper boiler and half the lower boiler-surface; for cylindrical boilers, not more than 60 feet long, all the heating surface.

To the above must be added a battery for relay in case of cleaning, repairs, etc., and more than one battery extra in large plants, when the water carries much lime.

For anthracite practice, add 50 per cent. to above calculations. For charcoal practice, deduct 20 per cent.

DISCUSSION.

MR. P. BARNES: I have been very much interested in Mr. Gordon's paper, and would like to ask what is found by actual determination to be the temperature of the outgoing gases.

MR. GORDON: We have found it as high as 700° F., and as low as 400° F.

MR. W. F. DURFEE: I have had some experience with blast-furnace boilers that may be of interest. Some years ago, on taking charge of a large works, I found two blast-furnaces the boilers of which were 64 feet long and 42 inches in diameter. Each of these boilers were suspended at five points. Just exactly which or how many of those points supported the boiler was something which, as Lord Dundreary might say, "no fellar could find out." There was a great deal of irregular expansion, causing a change of form in the boilers, their front ends usually rising as the temperature increased. Pending some preparations for changing the method of their suspension, one of these boilers burst. About one-third of the circumference of the second joint from the front-head was ruptured through the rivet-holes, and all the contents of the boiler escaped through the rent without causing other serious damage. The remedy for the troublesome behavior of these boilers which I adopted was this: Without removing them from their settings, or at all interfering with the running of the furnaces, I cut them in two at their middle, one at a time, and put a head into each half. These heads, when the job was completed, were four inches asunder, and this space was covered at the top with a curved plate resting upon the boilers to prevent the ingress of air. The rear half of the divided boiler was connected with the front by two curved copper pipes, one for the water, and the other for the steam-circulation. Each half of the original boiler was, after the above-described changes, nearly 32 feet in length, and was suspended to two cross-girders or saddles, so placed that each saddle sustained half the weight of the boiler. There was no change whatever made in the brick-work of the boiler-setting, the completed arrangement being simply two plain cylinder boilers placed end to end, having their steam and water spaces properly connected with curved pipes for circulation, and to admit of the independent expansion of each boiler. This arrangement is believed to accomplish, with a much smaller expenditure of money, all that any elaborate system of spring and lever suspensions can do.

THE PHYSICAL PROPERTIES OF COKE AS A FUEL FOR BLAST-FURNACE USE.

BY JOHN FULTON, JOHNSTOWN, PENNA.

EARLY in the year 1875, some difficulty was experienced in the "Old blast-furnaces" of the Cambria Iron Company, at Johnstown, Pennsylvania, arising from the increased use of native coke, prepared in Belgian ovens near the furnaces, in mixture with Connellsville coke, in the production of Bessemer pig-iron.

This was the more surprising at that time, because a very complete coal-crushing and washing apparatus, after the Bradford plan, had just been put into successful operation, affording a pure coal for coke-making. It was confidently expected that this thorough cleansing of the coal would improve the quality of the coke and fit it for the increasing manufacture of Bessemer pig-iron.

But the trouble with the native coke continued. Experiments in fuel charges—increasing and reducing them—failed to correct the irregular working of these furnaces. Increasing the charge of native coke produced abnormal heat at the top of the furnace, reducing it cooled the furnace below.

At this stage of affairs, the Hon. Daniel J. Morrell, general manager of the Cambria Iron Company, requested the writer to make the requisite investigation to determine the nature of this coke-difficulty, and to ascertain why the Johnstown coke could not be used in blast-furnace work as well as Connellsville. This task at first did not appear to present any special difficulties, but subsequently it expanded into proportions that caused no little anxiety.

The first effort was directed to procuring average samples of Johnstown and Connellsville coke. At this period of the investigation, it was assumed that the whole matter could be intelligently solved by comparing the chemical analyses of the two cokes:

	Johnstown Coke.	Connellsville Coke.
Moisture,	....	0.30
Volatile matter,	....	0.46
Fixed carbon,	90.48	89.57
Ash,	8.96	9.11
Sulphur,	0.56	0.82
Phosphorus,	....	0.014
	100 00	100.274
Analysts,	T. T. Morrell.	A. S. McCreath.

An inspection of the above results showed that the chemical elements in the two varieties of coke were practically equal in calorific value. It was also evident, that this method of examination alone would fail to disclose the cause of the inferiority of Johnstown coke.

Just what line to pursue in future research was not at once apparent. There was no doubt, however, that the bad working of the furnaces was due to the coke.

The only way out of the difficulty seemed to be in an examination of the literature of the subject; for I assumed that a matter of such prime importance in metallurgical operations, would have received a large share of attention.

Examinations of papers in the annual volumes of the North of England Institute of Mining Engineers afforded much valuable matter on the methods of coking, but did not throw light on the question under consideration. The volumes issued yearly by the Smithsonian Institution were consulted, but they afforded no help. It would be tedious to mention the works examined in this anxious search after the properties of good furnace-coke.

A few days were next devoted to a careful study of furnace-fuels, charcoal, coke, and anthracite coal. Typical specimens of each were laid on my table, and examined frequently. To the naked eye these fuels appeared quite different—the soft charcoal, the hard glossy anthracite, and the intermediate silvery coke.

Did a unit of carbon in all of these forms of fuels afford equal results in heat-calories in blast-furnace use? If so, why should there be found in actual use any difference in calorific energy? Why was Johnstown coke, possessing an equal value in carbon with Connellsville, inferior to the latter in blast-furnace work?

It occurred to the writer at this time, that the cause of difference in furnace-fuels of equal carbon value must be attributed to their *physical structure.* A careful examination of the three fuels with a microscope followed, disclosing differences of structure distinctly characteristic of each class of fuel.

The very dense glossy anthracite shows mere traces of flattened disks suggesting cell-structure, and generally, also, the laminated structure of the coal-deposit. The coke shows a silvery-bright metallic appearance, with well-defined cells or pores of different sizes, indicating, in the best qualities, thorough fusion, and affording no evidence of lamination, or of the structure of the coal from which it has been made. There are a few exceptions to this structure—nota-

bly the coke or rather *charred coal* from the "Block-Coal" of Indiana, which retains the coal-structure, just as charcoal retains the wood-structure. Charcoal shows composite cell-pores, in irregular stratified groups of different sizes, recording the annual formation of pores in the growth of the wood.

This examination afforded the first light on the subject, and indicated the method to be pursued in future work. It also suggested, in part, the cause of the difference in value of fuels in blast-furnaces.

Anthracite coal and charcoal had already afforded satisfactory evidence of their value in blast-furnace operations; and the Connellsville coke had also, in its use in the Lucy furnace, at Pittsburgh, displayed its calorific energy by producing a weekly yield of over 700 tons, which, at the time (1875), was regarded as very extraordinary work, so that the inquiry was now reduced to the single question, What is the matter with the Johnstown coke?

In the further examination, in the endeavor to satisfactorily answer this inquiry, it was assumed that, other things being equal, the calorific energy of a blast-furnace fuel is in proportion to *the surface afforded to the oxygen of the blast* in the region of the tuyeres. To determine the respective cell-spaces of Connellsville, Johnstown, and other cokes, accurate cubes of one inch were cut from the best specimens of each class of cokes. These were dried at 200° F., and weighed dry. They were then placed in a glass of distilled water, under the receiver of an air-pump, and the air was pumped partly out of the cells and pores, permitting the water to be drawn into these spaces. The wet cubes were then weighed and the difference was noted.

Cubes of coke were used for the reason that they afforded the best form for making the additional test of *compressive strength*, indicating their relative hardness, and consequent ability to resist the action of the gases in the upper regions of the furnace, and sustain the burden without crumbling.

In the determination of the ratio, in coke, of body to cell-space, it was assumed that the specific gravity of water was approximately the same as that of coke. This was designed to meet the actual conditions by excluding the 10 per cent. of slate in coke. The cubes were cut out of the inside of pieces of coke, and had the maximum development of cells.

It may be noted here, that however accurate this method of determination of the spaces of cells and pores in coke may be, the

result can only afford an approximate estimate of cell-walls to cell-spaces.

When absolute accuracy in this inquiry is attained, the superficial area of cells and pores exposed to the action of the gases in a furnace, must be determined. For this purpose the relative sizes of the pieces of each kind of coke or other fuel must be taken into calculation, for the more diminutive the pieces, within certain limits, the more surface will be exposed to the action of the gasses, and hence the greater the energy of the fuel.

The appended table is the first table of 1875.

In the review of this table, some contradictory and perplexing results were encountered. For instance, the inferior Johnstown coke showed more cell or pore space than the superior Connellsville coke: the latter showing 62 per cent. of coke to 38 per cent of cell space, and the former averaging 57 per cent. coke to 43 per cent of cell-pores. On the other hand, the compressive strength of Connellsville coke was found to be 284 pounds to the cubic inch, whilst the Johnstown coke sustained only 245 pounds, clearly showing the softness of the latter, and indicating the true cause of its inferiority, viz., *softness of body causing it to be ignited in the upper regions of the furnace,* not only wasting its heat there, but disarranging the operations of the furnace.

From these results, corroborated by furnace-practice, the desirable properties of good metallurgical coke have been deduced—hardness of body, and well-developed cell-structure. This led to a still further inquiry into the effects of the three principal methods of coking on the physical properties of the coke produced by each kind of oven. These were published in volumes L and G of the *Reports of the Second Geological Survey of Pennsylvania,* under the direction of Professor J. P. Lesley, State Geologist.

During the intervening years, from 1875 to 1883, the study of coke has been kept up incidentally, as to its mode of preparation, quality of coal, and physical properties of coke, embracing the examination of samples from many states and foreign countries. The old table has been expanded, and much additional evidence secured, which it is believed will enhance the practical accuracy of the results.

In the recent progress of rapid furnace-work in the production of Bessemer pig-iron, the chief requirement of coke-fuel is becoming *hardness of body.* At this day any intelligent furnace-superintendent will settle the relative value of cokes in a few minutes by rub-

Table exhibiting the Physical Properties of Coke for Furnace Use, produced from the Typical Coking Coals of Pennsylvania, by the Three Methods now in Use.

Locality where Made.	Method of Coking.	Grammes in One Cubic Inch.		Pounds in One Cubic Foot.		Per cent. of Coke.	Per cent. of Cells.	Compressive Strength per cubic inch in pounds (1/4 Ultimate Strength).	Height of Furnace-charge which can be supported without crushing.	Order of magnitude of Cells in Coke.
		Dry.	Wet.	Dry.	Wet.				Feet.	
Cambria Iron Co. Bennington,	Open pits,	13.36	19.74	50 90	75.20	67.68	32.32	281	112	I.
Broad Top, Broad Top,	Open pits,	12.00	19.59	45.72	74.53	61.25	38.75	220	88	I.
Connellsville, 72 hour Coke,	Beehive ovens,	12.46	20 25	47.47	77.15	61.53	38.47	284	114	I.
48 hour Coke,	Beehive ovens,	14 02	20.95	53.41	79.81	62.92	33.08	249	100	I.
Kemble C. & I. Co. Broad Top,	Beehive ovens,	11.76	20.18	44.81	76.88	58.27	41.73	240	96	I.
Cambria Iron Co. Johnstown,	Belgian ovens, average,	11.50	20.06	43.82	76.41	56.80	43.20	245	99	III.

bing pieces against each other; the piece suffering the least by abrasion being the better coke. In such a test the purity of the cokes is assumed as practically equal.

From all the results of the use of coke which the writer has thus far been enabled to gather, the four following conditions are regarded as essential in coke designed for blast-furnace use in the production of Bessemer pig iron:

I. Hardness of Body.
II. Well-Developed Cell-Structure.
III. Purity.
IV. Uniform Quality of Coke.

I. Hardness of Body.—The best coke must possess *hardness of body or cell-walls*—not density, for dense cokes are frequently soft or punky, whilst hard cokes generally afford a well-developed cell-structures. These two physical properties, hardness and full cellular spaces, are correlated, just as softness of body, and diminutive cells or density are associated.

This prime requirement of hardness of the body of the coke will be evident when the conditions of its combustion in a blast-furnace are considered. In its movement down the furnace, it is enveloped in a bath of hot carbonic acid gas. This gas possesses the power of oxidizing carbon or coke, and is especially destructive of the soft variety. Every pound of coke consumed by the gas in the upper region of the furnace is a *double loss*, by the reduction of temperature where the action takes place, and the loss of fuel, which should have been burned near the tuyeres.

I. Lowthian Bell has shown by direct experiment,* that all forms of carbon are not equally easily affected by carbonic acid, and that hard coke is capable of resisting its solvent action much more than soft coke, the latter suffering by oxidation, during a test of thirty minutes, six times the loss of the former.

The value of a coke possessing a degree of hardness which makes it less susceptible of oxidation, in the region of the furnace *where its combustion involves a double loss*, needs no further emphasis.

II. Well-Developed Cell-Structure.—Next to hardness of body in coke, a well-developed cell-structure is second only in importance. This arises from the fact that, other things being equal, the useful calorific energy of a blast-furnace fuel is in proportion to

* Chemical Phenomena of Iron Smelting, pp. 413, 414.

the surface exposed to the oxygen of the blast in the region of the tuyeres. Hardness, with density of physical structure, as found in anthracite, which is a natural coke produced under great pressure, illustrates this position conclusively by its actual work. The following records, illustrate this difference in density, with corresponding results, in blast-furnace running on Connellsville coke and anthracite coal.

Connellsville Coke.—The run of the Carnegie Brothers & Co.'s Edgar Thomson "E" furnace, at Pittsburgh, for the three weeks ending November 11th, was 1465 tons, 1629 tons, and 1540 tons respectively. This output was on 54 per cent. ore, and was made on 1 pound of coke to 1 pound of iron. Their "D" furnace has made 299 tons in one day, 1840 tons in seven, and 7332 tons in thirty-one consecutive days. The ton used is 2268 pounds.

Anthracite Coal.—The yield of pig-iron at Colebrook furnaces during the week ending Saturday, December 16th, was 577 tons at No. 1 Furnace, and 575 tons at No. 2 Furnace. The total yield for the week from both stacks was 1152 tons. No 1 furnace has been in blast fourteen weeks, and has produced in that time 6446 tons of pig-iron, averaging 460 tons per week. No. 2 furnace has been in blast five weeks, and produced in that time 2389 tons, averaging 478 tons of pig-iron per week. Cornwall ore was used exclusively; the fuel used was anthracite. These are the two new furnaces of Robert H. Coleman, at Lebanon, Pa. No. 1 is 55 feet high by 14½ feet in diameter; No. 2 is 80 feet high and of the same diameter as its mate. The ton used contains 2250 pounds.*

In general, it may be said that the average efficiency of coke and anthracite as blast-furnace fuels may be represented by the relative production of 800 tons and 500 tons of pig-iron per week.

This exhibits a relation of Connellsville coke to anthracite coal of 8 to 5. A careful test of two cokes differing in density, made at Connemaugh furnace, showed a loss of 11 per cent. in product arising from the denser coke alone.

III. Purity.—Sulphur, free or combined with iron, is mainly found in the coal-slates. In some instances these slates are interleaved in very thin plates with the coal, so as to render washing unsatisfactory. In other coals the pyrites are found in lenticular pieces, which are readily removed by crushing and washing. Hence it follows, in a general way, but not always, that the more slate the more sulphur. Mr. McCreath has shown that twenty-five coals

* The Iron Age, January 4th, 1883.

examined, containing an average of 2.138 per cent. sulphur, yielded cokes containing an average of 1.912 per cent. of sulphur.

Phosphorus is a more difficult element to locate. The inquiry as to the relative amounts in the coal and its slates will probably be answered when Professor J. P. Lesley arranges the valuable data now being collected by the second geological survey of Pennsylvania. Mr. Britton found in two samples of anthracite coal for furnace use: ash, 10.43; phosphorus, .049; and ash, 5.29; phosphorus, .0354. In examining two semi-bituminous coals he found in one, ash, 5.03; phosphorus, .0085; and in the other, ash, 4.94; and phosphorus only a trace.* In a recent series of tests for phosphorus in brown hematite iron ore, an average of .099 was found in clean ore, .068 in the clay in the ore, and .012 in the rock-matter associated with the ore.

One general principle can be safely deduced from the foregoing data, that the less ash there is in the coke the less risk of the increase of sulphur or phosphorus in the resultant pig-iron. In many cases there is danger of injuring the physical condition of coke by the operation of washing the coal free from slate. The washing of some coals improve the coke, in others it injures it.

In the discussion of this matter at the Hazleton meeting of the Institute of American Mining Engineers, in 1874, Mr. Bell further remarked, as to the relative value of coke made from washed and unwashed coal, that he was of the opinion that coke made from coal that did not require washing was superior to that made from washed coal.† Washing coal removes valuable hydrogenous matter, which aids in developing cell-structure. In other words, in many cases the loss in calorific energy by the increased density of the coke from washed coal, would more than overbalance the advantage of a reduction of ash, excepting where the original ash is excessive.

IV. Unifomity of Quality of Coke.—This is a very important requirement, in view of the destructive action of carbonic acid gas on soft coke. The "black ends," which are sometimes made in coking, are worse than useless in a blast-furnace; and if their weight is reckoned in the fuel-charge, bad results must follow. Hence a carefully-prepared coke, alike all through, is most desirable for regular and vigorous work.

These principles, the result of some years' study, have been embodied in the new table, enlarged from the old table of 1875, as follows:

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* Transactions of American Institute of Mining Engineers, i., 228,

† Transactions, iii., p. 182.

Table exhibiting the Physical and Chemical Properties of Coke.

Locality.	Grammes in One Cubic Inch.		Pounds in One Cubic Foot.		Percentage.		Compressive Strength per cubic inch (¼ Ultimate Strength).	Height of Furnace-charge, supported without crushing	Order in Cellular Space.	Hardness.	Specific Gravity.	Chemical Analysis.						Analysts and Remarks.
	Dry.	Wet.	Dry.	Wet.	Coke.	Cells.						Fixed Carbon.	Moisture.	Ash.	Sulphur.	Phosphorus.	Volatile Matter.	
Connellsville, .	12.46	20.25	47.47	77.15	61.53	38.47	284	114	1	3 50	1.500	89 57	0 30	9.11	0.82	014	.460	A. S. McCreath.
West Virginia, .	13.76	21.19	52.54	81.56	64.32	35.67	258	103	1	3.15	. . .	92.18	0.11	6.68	0.618	.027	.350	J. B. Britton.
Broad Top, . .	11.76	20.18	44.81	76.88	58.27	41.73	240	96	1	3.35	1.342	89.28	. . .	8.66	1.06	. . .	. . .	T. T. Morrell.
Clearfield, . .	14.79	19.86	56.35	76.69	74.43	25.57	319	128	1	3.60	1.560	89.86	0.54	9.41	. . .	. . .	.667	Booth, Garret & Blair.
Cumberland, .	12.76	21.63	48.61	82.41	58 99	41.01	215	86	1½	3.00	1 750	. . .	. . .	. . .	. . .	. . .	. . .	Soft Coke.
Alabama, . .	13.30	18.29	50.70	69.01	73.77	26.23	225	87	1	3.50	1.493	. . .	. . .	. . .	. . .	. . .	. . .	Good Coke.
Illinois, . . .	11.06	17.09	42.02	65.09	63.79	36.21	180	70	1	3 20	1.215	89.77	0.12	9.58	0.93	.033	. . .	Good Coke. T. T. Morrell.

It will be noted that the chief properties relied upon from 1875 until the present are the hardness of the coke and its open cellular structure. Indeed, recently the bulk of evidence from rapid-driving furnaces has concentrated on the importance of hardness of the body of the coke, the cells being of subordinate importance; for it has been shown that hard cokes, with a low ratio of cells, have sometimes a slender stalactitic structure, produced in coking; the increased surface thus afforded to the gases of the furnace compensating for the smaller proportion of cells.

As a general rule it has been found that the properties of coal which produce complete fusion in coking and yield hard coke afford also a well-developed cell-structure.

It may be well to bear in mind that the size of furnace, quality of ore, and heat and pressure of blast, are important elements in the determination of the requirements for coke-fuel.

Until quite recently two principles seem so have governed the methods of coking,—economy of production and large percentage of yield of coke. The production of the most desirable physical condition of this fuel for furnace-use, by diversified methods of coking, has not yet received the attention its importance demands. This inattention to methods of coking has been largely caused by the ease with which coke of the best quality is produced in the Connellsville region.

In the issue of *Coal*, February 14th last, the editor, in a review of the writer's article on the comparative values of coke, remarks:

"We cannot help believing that some of these differences could be overcome if in other districts the Connellsville coking methods were not blindly followed. What is good practice in one section is not necessarily the best in another, and until in each the right temperature of coking is struck by careful experimenting. A glance at the table would lead us to believe that quicker coking,—that is, a higher temperature, would do the West Virginia, and particularly the Illinois coke, good, while the Clearfield would be improved—that is, made more open—by slower coking."

The Illinois Central Iron Mining and Coal Company has been using a more rapid mode of coking by sustaining the heat in its oblong ovens (36′ x 8′ x 4½′ high,—Thomas's patent), by pushing out the hot coke and quenching on the outside of the oven. The result has been very satisfactory.

The use of superheated steam, in coking lignite, has been for many years in practical operation at Vordenburg, Austria. The

final temperature in this or similar operations in Germany was found, by F. Fischer, to be 450° C.

Whether the heat of coking, in slow or quick methods, will enable one to control the process in ovens with shallow, horizontal charges, on the principle of the beehive, or whether some pressure must be used by deep charges, after the principle of the Belgian or Appolt ovens, to repress a tendency to inflated physical structure, must be determined by experiment. One thing seems clear, in all coking operations: that no application of heat or pressure should be made which would tend to make a coke which would approximate to the undesirable dense structure of anthracite coal, or, as it may be called, natural coke, made under immense pressure. If rapid heating is required, oblong ovens, *with or without flues*, could readily be adopted without the deepening of the coal-charges, which would have the effect of producing an undesirable density in the coke.

From these considerations it appears that the character of the coal to be coked is first to be considered, and that the kind of oven and its heat-requirements follow.

During the year 1880 an effort was made to ascertain how the best varieties of coking-coals could be known by a ready test. A number of the well-known prominent types were experimented on for their capacity to reabsorb moisture from the atmosphere during two hours' exposure, after having been dried to 212° F. The results, however, did not justify the experimenter in coming to definite conclusions. The only sure test for the coking properties of coal is in the large way, having an ovenful coked by quick or slow heats, and the product examined carefully.

The forthcoming report of Joseph D. Weeks, Esq., of Pittsburgh, special expert of coke-industries of the tenth census, will be found a most valuable and exhaustive work on all that pertains to the history, manufacture, and use of coke in the United States and other countries.

At the June meeting of the Institute at Roanoke, Va., Mr. Frederick P. Dewey, of Washington, read a paper on the "Porosity and Specific Gravity of Coke," in which he takes occasion to say that, "the facts on record of its physical properties are exceedingly meagre; and this is also true, but in a less degree, of its chemical composition. An investigation is being carried on in the National Museum which is intended to supply, so far as may be, this deficiency." Professor Baird, Director of the Museum, permits him to present to the Institute a summary of the results already obtained.

"So far as I am aware, the only attempts to determine experimentally any of the physical properties of coke, are those made by Mr. John Fulton, mining engineer, of the Cambria Iron Company."

In reply to the criticisms of my work in Mr. Dewey's paper I would say that in the method of the writer, in 1875, it was designed to eliminate the readily available cell-spaces, making allowances for the maximum cell-spaces found in a cube cut necessarily from the middle of a piece of coke, and excluding the 10 per cent. to 15 per cent. slate matter in the coke. The relation of body of coke to the cellular space found in this way was, in Connellsville coke, 61.53 per cent.; 38.47 per cent.

Mr. Dewey gives the percentage in Connellsville coke as follows: "Coke, 51.61 per cent.; cells, 48.39 per cent."

Both of these methods are only approximate. This arises from the fact that the mere cellular space has not been and cannot be used as an element in the practical determination of the value of cokes for blast-furnace use. Furnace-gases cannot act on *cell-spaces;* they can only act on *exposed surfaces.* The determination of cellular spaces merely corroborates the inspection of cells by the microscope.

As before submitted, an *accurate method* must determine the relations of the solid parts of the coke to the surface afforded by the inclosing walls of its cells and pores.

The writer has always been careful to accord his associates full merit for their helpfulness in the coke-determinations; but he claims exclusively the origination of the methods of examination.

AN ACCOUNT OF A CHEMICAL LABORATORY ERECTED AT WYANDOTTE, MICHIGAN, IN THE YEAR 1863.

BY W. F. DURFEE, BRIDGEPORT, CONN.*

In the year 1862 the author of this paper was called upon to design and superintend the erection and working of the machinery of an experimental works for the production of steel by a process

* Mr. Durfee prefaced the reading of this paper with the following remarks:

MR. PRESIDENT: Before proceeding with the reading of my paper, I desire to thank you for your kindly words relative to my work at Wyandotte,—a work, as compared with the immense improvements in methods and machinery, since effected by the labors of the late A. L. Holley, the Fritz Brothers, and many other "good men and true," was full of imperfections; but I claim for it that it was as good

discovered by Mr. William Kelley. These works were located at Wyandotte, Michigan. Mr. Kelley's invention was, as is now well-understood by all who are familiar with metallurgical matters, identical in principle with that which is now known all over the world as the "Bessemer process." Very soon after entering upon the study of the theory of the process (for practice at that date in this country there was none) it became evident to me that an accurate knowledge of the chemical constituents of the metals and other materials employed was essential to its successful conduct. I reasoned that as all pig-irons did not form the basis of equally good wrought irons, so there was no probability of uniformly good steel being produced from miscellaneous metal; and, further, that while in the then state of our knowledge, it would be impossible to predict from chemical analysis just what was the best iron for the new process, it would be possible, after having demonstrated by experimental working that certain irons were, and others were not, suited for our purpose, to make an analytical comparison of them, the result of which would be a permanent guide for future operations, enabling us to determine by analysis and comparison, whether any offered

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pioneer work as was ever done in the early days of any invention, the development and improvement of which has largely augmented the happiness of mankind.

Neither the steam-engine of Watt nor the locomotive of Stephenson would at this day be regarded as an example of good mechanical design. The ships of Columbus would not now be considered the best models of naval architecture, but they accomplished their purpose by successfully encountering the perils of unknown seas, and revealed to admiring nations the wonders of a New World At the time when the experimental works at Wyandotte were designed and erected, the promoters of the new method of decarbonizing pig-iron, now known as the "Bessemer process," were without a lamp to their feet or a guide to their path, groping with "unsteady step and slow" in a darkness where everything was "without form and void," in search of the means by which to practically realize those results which a firm and unwavering faith in the undertaking which they had in hand told them were possible. In those early days, the atmosphere in which I moved was heavy with a fog of discouragement. All the so-called "practical iron men" in the vicinity of Wyandotte were opposed to the new enterprise. I well remember the sneers of contemptuous incredulity which greeted my statement, that the time would come "when a steel rail could be made cheaper than an iron one;" and now that that time has arrived, as I look back upon my early work with the added experience of twenty years to aid the retrospection, I do not hesitate to claim that it was as good a solution of the problem presented, as was possible under the circumstances of time and environment.

If the paper which I am about to read, descriptive of the chemical work undertaken at Wyandotte accomplishes no other purpose, it will at least serve to break that "singular silence," so significantly referred to by Mr. Forsyth (in his paper on the Bessemer plant of the North Chicago Rolling Mill Company), as existing on the part of "all those connected with the early work at Wyandotte."

brand of iron was of suitable quality, thus saving a large outlay for direct experiment in the "converter," and serving as a check upon the running of the blast-furnace, as well as a guide in the purchase of metal and other materials. These considerations, and others of an administrative character, determined the construction of a chemical laboratory as an adjunct to the works. The importance of a thorough knowledge of the chemistry of the new process, and the necessity for a laboratory in close proximity to the proposed works, to facilitate the attainment of such knowledge, was promptly recognized, and the construction of the laboratory cordially approved by the late Z. S. Durfee, who was acting as secretary of the parties in interest (of whom he was one); and in the spring of the year 1863, he secured the services of Mr. Emile Schalk, a native of Germany, and a graduate of the École Centrale of Paris, as chemist. Mr. Schalk purchased a stock of chemicals, together with necessary glassware and other apparatus for use in the laboratory; but as the building was not completed when he reached Wyandotte, he, at the request of the late Captain E. B. Ward, assisted in the organization of an exploring party, which he accompanied to Northern Wisconsin. The result of this expedition was the discovery of a number of deposits of iron-ore. On Mr. Schalk's return in October (1863), the laboratory being finished, he at once proceeded to analyze samples of the ores he had discovered. I am able to give his analysis of four of these samples.

SAMPLE 1.

Iron,	59.70
Oxygen,	22.47
Silica,	17.65
Magnesia,	.16
Nickel,	trace
Loss,	.02
	100.00

SAMPLE 2.

Iron,	53.39
Oxygen,	20.18
Silica,	26.20
Magnesia,	.20
Nickel,	trace
Loss,	.03
	100.00

SAMPLE 3.

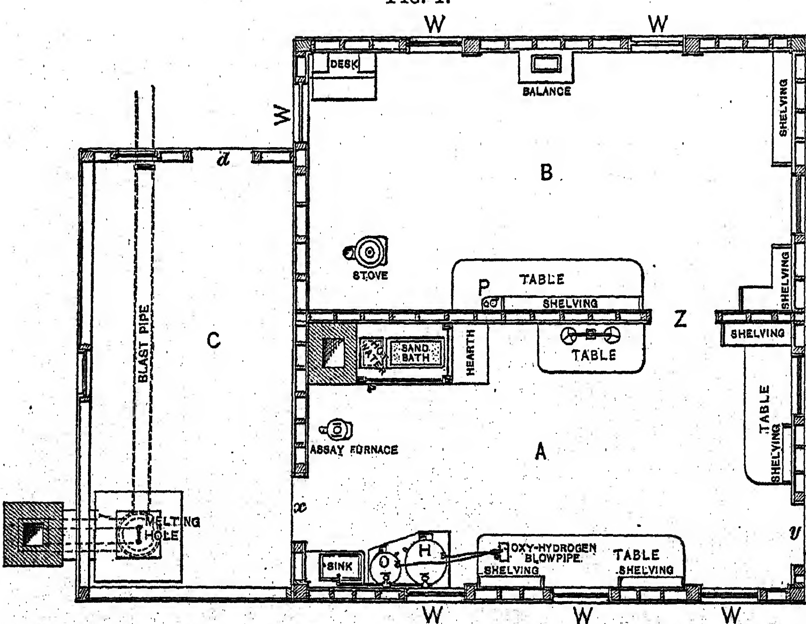
Iron,	50.16
Oxygen,	19.81
Silica,	29.40
Magnesia,	.60
Nickel,	trace
Loss,	.03
	100.00

SAMPLE 4.

Iron,	49.90
Oxygen,	19.01
Silica,	30.02
Magnesia,	.90
Nickel,	trace
Loss,	.17
	100.00

Mr. Schalk also commenced some original investigations with a view to the determination of the influence of nitrogen upon steel.

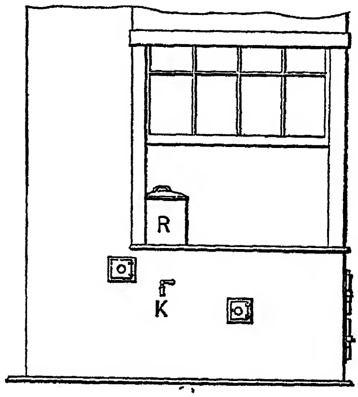
FIG. 1.



These promised to develop very interesting and valuable results, but, unfortunately, circumstances for which Mr. Schalk was in no way responsible, caused his resignation in December, 1863, before they were completed. Of Mr. Schalk's abilities I had the highest estimation, and I very much regretted his departure from Wyandotte.

Having described the inception and initial work of the Wyandotte Laboratory, I will now call your attention to its arrangement, and also to some of the apparatus employed. As shown by the plan (Fig. 1), the main building was about 24 feet square; it was divided by a

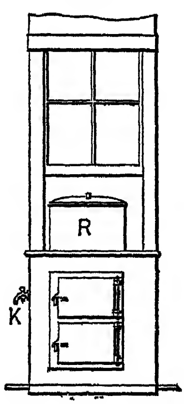
FIG. 2.



Front Elevation.

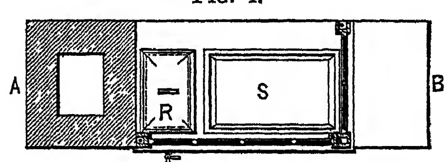
partition into two rooms, A and B, of equal size, which communicated by a door at Z. At the rear of this building was a lean-to shed, C, which was entered from without by the door *d*, and from

FIG. 3.



End Elevation.

FIG. 4.



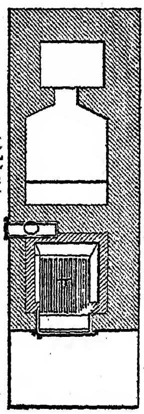
Plan.

within by the door *x*, communicating with the room A, at the opposite end of which was placed the entrance-door *y*.

The room A was used for general analytical work; it was provided with three work-tables, the requisite shelving for reagents and

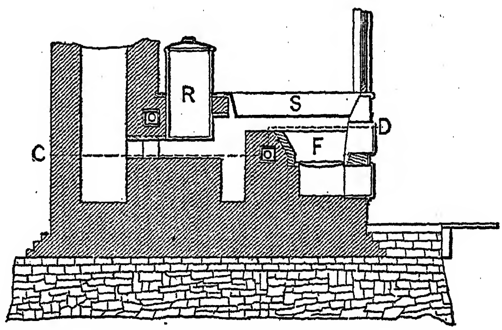
apparatus, a large pair of balances, a sand-bath furnace having a hot-water reservoir attached, a small assay furnace, a sink, an abundant supply of water, and an oxy-hydrogen blow-pipe, the gas-holders of which were located at O,H. The room B was provided with

FIG. 5.



Section through C D in Fig. 6.

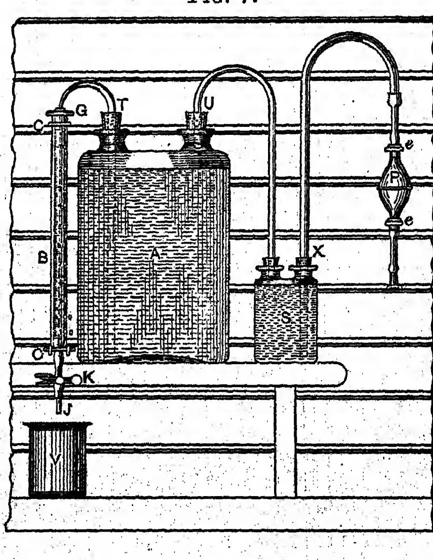
FIG. 6.



Section through A B in Fig. 4.

a stove, a desk, assay balances, shelving for specimens of minerals and metals, and a work-table having a case of shelves above it, at the end of which, at P, was placed an apparatus by which permanganate

FIG. 7.



of potassa was used for determining the amount of metallic iron in a solution of its protochloride by titration. Of the construction of

this apparatus I shall presently give the details. The rooms A and B were about 18 feet in height, and were amply lighted by the windows, W.

In the corner of the lean-to shed, C, was placed a "melting-hole" large enough to receive a pot containing 70 pounds of melted metal. For convenience this melting-hole was placed on a level with the floor of the shed, and blast was supplied from the blowing-engines of a neighboring furnace by means of an underground pipe. In the room C was kept a stock of crucibles, the tongs, and other tools used for working the "melting-hole," an anvil, hammers of several sizes, an iron mortar and pestle, and sundry supplies such as clay, sand, charcoal, etc. The sand-bath furnace was located in one corner of the room A (Fig. 1). Its construction is illustrated in Figs, 2, 3, 4, 5, and 6. The basin, S, for holding the sand was made of wrought iron, $\frac{1}{4}$ inch in thickness. The water in the copper reservoir, R, was kept at or near the boiling-point by the waste heat from the fire at F. The reservoir was provided with a cock, K, for drawing off its contents. Two drying ovens, O, of copper, were imbedded in the brick-work. The inclosed space above the sand-bath was provided with weighted sashes on its front and right-hand end, and was ventilated at its top by an opening into the chimney-flue. This construction of sand-bath was found to be very convenient.

The permanganate of potassa apparatus is illustrated in Fig. 7. Though the same in principle, it is not of the precise construction as that used at Wyandotte, but contains some improvements, the result of experience, which render it more substantial and convenient. The apparatus consists of a large two-necked bottle, A, for holding the permanganate solution, to the left-hand neck of which is adapted a glass tube, T, which extends nearly to the bottom of the bottle, its upper end being tapered and curved so that its extremity is directly above the centre of the upper end of the graduated "burette," B. This "burette" is supported by the clamps C, C, from which it can readily be removed for cleaning; its lower end is provided with a pinch-cock, K, having a glass adjutage, J. When the apparatus is not in use, there is a piece of plate glass, G, interposed between the top of the "burette" B, and the outer end of the tube T; this effectually prevents dust from entering either the "burette" or the tube. To the right-hand neck of the bottle A is fitted a tube, U, whose inner end communicates with the space above the solution in the bottle, and after passing through the cork, and curving through an angle of 180°, it descends perpendicularly, and passes through the cork in the left-hand neck of the small two-necked bottle S. into

the space above the concentrated sulphuric acid, with which the bottle is nearly filled. The right-hand neck of this bottle has adapted to it a glass tube, X, whose inner end passes nearly to the bottom of the bottle, outside of which the tube ascends above the level of the top of the bottle A, and then by a semicircular curve to the right it reaches the upper end of the air-pump P, which is supported by a couple of screw-eyes, *e*, *e*, at such a distance from the wainscoting as to admit of the hand readily grasping the bulb of the pump.

When we wish to fill the "burette" with the permanganate solution we proceed as follows: The glass plate G is removed, and the air-pump P is worked; thus forcing air, by way of the tube X, into and through the concentrated sulphuric acid in the bottle S; this acid arrests all the moisture and organic matter in the air, which then passes through the tube U, into the space above the permanganate solution in the bottle A; as the pressure increases the permanganate rises in the tube T, and finally runs into the "burette" in a stream whose flow is easily controlled by the more or less rapid working of the air-pump P; in fact, as the level of the solution in the "burette" approaches the zero of its graduation, the stream can be made to resolve itself into a series of rapidly-succeeding drops, which can be promptly arrested by stopping the action of the air-pump P. From the "burette" the permanganate solution can be drawn by the pinch-cock K into the solution of proto-chloride of iron contained in the beaker V, rapidly or slowly, as the rate of oxidation requires. The apparatus described, when once arranged and provided with a properly standardized solution, is more available and convenient than any other within my knowledge intended for a similar purpose.

At the time of which I am speaking, among the many practical questions that were presented for solution, that relative to the material for lining the converting vessel was a most difficult and important one. The requisites for a good lining appeared to me to be these:

1. It should at the outset be of a plastic or semi-plastic nature, to facilitate its solid compression between the brickwork in the converter and a removable core.

2. Its composition should be such as to admit of its being baked in place into a solid mass.

3. This mass should have sufficient cohesion to resist the mechanical erosive action of the turbulent fluid metal in the converter.

4. The lining should be able to withstand an exceedingly high temperature for a prolonged period without melting.

5. It should oppose a maximum resistance to the fluxing action of the highly heated metallic oxides and other impurities in the converter.

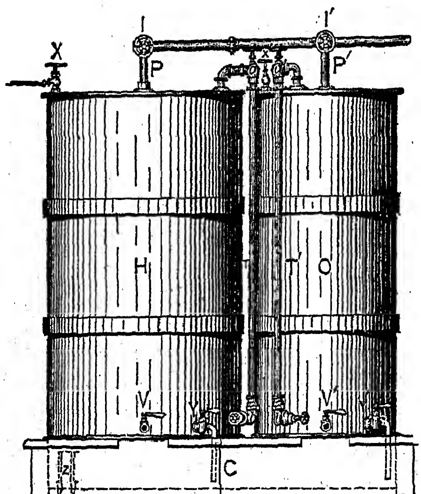
Experimenting in the converter with materials for linings I was sure would be very expensive, and, in the event of frequent failures, discouraging; it was, therefore, desirable to have as little of this as possible, and, with a view of throwing all obtainable light upon the question, I determined to institute a series of experiments on materials for converter-linings in the laboratory. It was clearly possible to bake in a melting-pot or a reverberatory furnace small bricks or balls of any combination of refractory materials, and these could be compared as to their friability and fusibility. It was evident that, in order to correctly compare the fusibility of the various combinations, it would be necessary to submit samples of equal weight to the action of as uniform and as high a temperature as it was possible to attain; and that, the temperature being uniform, the comparative fusibility of the various materials under investigation would be measured by the relative time required to melt each specimen. The difficulty of securing a uniform temperature by the use of any kind of solid fuel appeared to be insurmountable, and I therefore decided to use some form of gas-blowpipe; but there not being any gas-works in the town, it became necessary to select some form of gaseous fuel that could be readily produced of uniform quality in the laboratory. I could think of no combustible gas that could be generated in a state of uniform purity by the means at my command as easily as hydrogen, but in order to get the highest temperature attainable by its use, it was necessary to employ oxygen in connection with it. In short, I was naturally led, by the character of the proposed investigations and the nature of my environment, to the employment of the "oxy-hydrogen blowpipe." But the oxy-hydrogen blowpipe as to that date constructed was, for my purposes, defective in one particular, viz., no form of it with which I was acquainted had any certain provision by which the two gases employed could be sent to the point of combustion in exactly their combining proportions—two volumes of hydrogen with one volume of oxygen—and unless that result was attained the temperature of the blowpipe-flame would necessarily be variable, and no two experiments would be fairly compared.

This consideration caused me to devise what I believe to be a novel method of assuring the proper combination of the two gases; and it is to this feature, as well as to the general character of the apparatus

for holding them, that I now ask your attention. The two gas-holders, H, O (Fig. 8), intended respectively for hydrogen and oxygen, were made of galvanized iron. They were each strengthened by two circumferential bands of the same metal, and additional strength was given the hydrogen-holder by a bolt which united the centres of its ends. The two gas-holders were of the same height, but their respective diameters were such that the area of a cross-section of H was twice that of a similar section of O.

The gas-holders stand upon the cover of a shallow cistern, C, which, when the apparatus is in use, is filled with water. The gas-holders were supplied with water from an elevated reservoir by

Fig. 8.



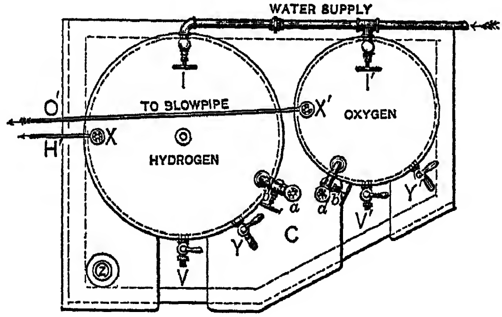
Elevation.

pipes, P, P¹, which, passing air-tight through their tops, extended nearly to their bottoms. The rate of admission of the water to each gas-holder was adjusted by the valves I, I¹; its function was to expel the gas from the holders through the small rubber tubes H¹, O¹, attached to the regulating valves X, X¹. Each of the gas-holders was provided with a glass water-gauge tube T, T¹, having valves, *a*, *a*¹, *b*, *b*¹, by closing which communication between each tube and the interior of the gas-holder to which it was attached could be cut off. Near the bottom of the gas-holders were located two cocks, V, V¹, and Y, Y¹, each of the latter having attached short pieces of tubing, which extended nearly to the bottom of the water in the cistern C, before named. This cistern is provided with a tubular overflow

plug, Z, which, when in place, determined the maximum depth of water in the cistern, and by the removal of which the cistern could be emptied. (See Figs. 8 and 9.)

Before describing the operation of the apparatus I will explain the method by which the holders were filled with gas, and for that purpose will ask you to suppose that we are about to fill the holder H with hydrogen. We first uncouple the rubber tube H^1 from the valve X, which we then open, as also the valves *a* and *b*, and make sure that the cocks V and Y are closed; we then open the valve I, and allow the water to fill the gas-holder, the air in which being expelled at the open valve X^1; but as soon as the water manifests itself at that valve it is closed, as also the valve I. The air having thus been expelled, and the gas-holder filled with water, we now couple to the cock V one end of an iron pipe, whose other end is

FIG. 9.



Plan

connected with the apparatus for generating the gas, care being taken that some point in this pipe is considerably higher than the top of the gas-holder. All the connections being properly made and the generator at work, we open the cocks V and Y, and as the gas enters the holder it displaces the water therein, which finds an exit through the cock Y into the cistern C, and finally over the top of the tubular plug Z into the drain-pipe, in which the plug is inserted; thus a certain depth of water is maintained in the cistern C, and as the pipe attached to the cock Y extends nearly to the bottom of this water, all air is prevented from entering the gas-holder during the process of filling it with gas. The rate at which the gas enters the holder is indicated by the descent of the water in the glass tube T, and the final completion of the filling process by bubbles of gas rising through the water in the cistern C, from the lower end of the tubular

extension of the cock Y; when these bubbles make their appearance the cocks V and Y are closed; the iron pipe connection to the gas generator is disconnected; and after coupling the rubber tube H^1 to the valve x the gas-holder H is ready for use. The gas-holder O is filled in the same manner with oxygen.

When this apparatus is used we proceed as follows: The valves I, I^1, are opened to their fullest extent in order to equalize the pressure in the two gas-holders; the rubber tubes H^1, O^1, are connected with the blowpipe; the valve X is partly opened, and the jet of hydrogen issuing from the blowpipe is ignited. The valve X^1 is then opened and so adjusted that the water rises in the gauge tube T^1, at the same rate as in the tube T; and when the water in these tubes rises with a uniform velocity, the two gases combine at the blowpipe, in the proportion of two volumes of hydrogen and one of oxygen, giving the maximum heat for the gas consumed; but it is evident that as the amount of heat developed in a given time will be proportioned to the gas consumed in that time, it is necessary to so adjust the valves X and X^1, that the same amount of gas is always consumed in a unit of time; for unless this were accomplished, no correct comparison of the fusibility of the several samples of refractory material under examination could be made. The samples of refractory materials to be tested were placed in a shallow cavity cut in a firebrick; this was surrounded with pieces of brick or tile to prevent access of currents of cold air.

The apparatus was found to give consistent results when repeatedly employed on samples of the same material, rounding of sharp corners, softening and fusion occurring after the lapse of practically the same time. It is advisable to bring the samples to a red heat in a crucible before subjecting them to the action of the blowpipe. This oxy-hydrogen blowpipe-apparatus was constructed during the year 1864, but owing to my time being occupied with more imperative matters, very little work was done with it, and what there was done had not that continuity from day to day which is always desirable in such investigations. Before I had sufficient leisure to give myself entirely to them, circumstances occurred which rendered such studies impossible in that locality. But before speaking further of these circumstances I will say a few words relative to the work actually accomplished in the laboratory. Numerous analyses of ores were made by Dr. S. P. Duffield, who for a time acted as chemist after the resignation of Mr. Schalk. Analytical work was undertaken by some whose zeal for the subtleties of science outran their

knowledge of material things. One young gentleman reported to me that a sample of $\frac{3}{4}$-inch round steel, sent me from England, and which was so mild that it was bent cold upon itself without crack, contained "7 per cent. of carbon," and insisted that, as he had "been unusually careful in his work," he must be correct. The same party, with a positiveness that would have carried conviction to a mind unacquainted with the possibilities of the case, assured me that it was "impossible to reduce iron-ore in a crucible in the pot-furnace," and proposed that I should erect a "miniature blast-furnace, in order that the ore should be smelted under the same conditions as obtained in the large furnaces." On my declining to do this, and actually reducing iron ore in the way he had pronounced impossible, he declared that a small blast-furnace was "better, any way;" and subsequently, in another community, he erected one at his own expense, only to find that it required sixty hours of continuous hard work to obtain two pigs of iron of the size of my forefinger.

Two of my assistants (one of the pair called himself a chemist) entered into an inventive conspiracy, and induced the late Captain E. B. Ward to furnish the money for certain experiments by which they were certain to demonstrate that the large blowing-engine I was erecting was "entirely unnecessary," their argument being that "all that was required to convert cast-iron into steel, was the forcing of abundant oxygen through it when melted, and, as water contained a large proportion of oxygen, the substitution of steam taken directly from the boiler for atmospheric air under pressure would greatly simplify and cheapen the process." The Captain was cautioned not to consult me in regard to the matter, as I would be "sure to condemn the idea"—in which statement they were quite right. These experiments were privately conducted in Detroit, and resulted in the loss of the Captain's money and the reputation of the experimenters at the same time. One of the last-named parties (not the chemist) asked what "that stuff in that little cup in the balance-case was for?" I briefly explained that it was "to absorb the moisture from the air in the case, and so prevent the corrosion of the steel parts of the balance." This was made a note of, and in a few days the young gentleman took some of the "stuff" to a young lady who had just received a present of a very valuable piano, and advised her to "put it in a saucer and place it in the piano to prevent the strings from rusting." This advice was followed, and resulted in the simultaneous ruin of the instrument, and of the popularity of the young gentleman.

One enthusiast, who firmly believed that the result of an analysis

was inevitably a realization of St. Paul's idea of faith, "the substance of things hoped for and the evidence of things not seen," at the particular request of the late Captain Ward did something which he called an "analytical examination" to a sample of coal. His report was so favorable as to its manifold good qualities, that the Captain purchased the mine from whence it came, only to find, after a large expenditure for pumping machinery, coal-cars, men's houses, and other plant, that there was not enough of this good coal in the mine or on the property to pay for working; hence lawsuits, tribulation, and sorrow. In justice to myself I will say that none of the parties whose antics I have incompletely described, were of my selection; they were thrust upon me, and I was obliged to make what use I could of them.

But let us now turn to some of the more serious and effective work accomplished by the laboratory. Some time in the year 1864, in conversation with the late Captain E. B. Ward relative to the economies possible in the manufacture of iron, I spoke of the fact that all the cinder resulting from the puddling of Lake Superior pig with Lake Champlain magnetic ore as "fettling" in his Wyandotte Rolling Mill was thrown away, instead of being utilized in the blast furnaces. "Why," examined the Captain, "Herr Unkunde Unheilschwanger* (then a leading metallurgical authority in Wyandotte) says there is no iron in the cinder." To my reply that there was "over 50 per cent. of good iron in it," he expressed a wish to "see some iron that was made from that cinder." I assured him that he should; and a day or two thereafter I placed in his hands a "button" of iron nearly as large as the palm of my hand, representing 55 per cent. of the cinder from which it was smelted in the pot-furnace of the laboratory. The Captain was not only surprised, but annoyed, at the evidence of waste in the past,—a waste that could be counted high among the thousands of dollars—and immediately gave orders to Herr Unkunde Unheilschwanger to see that this cinder was used in the blast-furnaces; but so alarmed was this worthy at the possibility of what he called "bunging up" the furnace, that he carried out his

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* The suggestion having been made to me that possibly, to many, this character "will seem like a slur on the German chemists and metallurgists as a class," I will here say that I have no intention of ridiculing any class of people except that which is wilfully *ignorant* and *full of mischief*, and therefore deserving of any and all forms of verbal punishment.

Herr Unkunde Unheilschwanger was not a German;—his speech being a variety of that dialect which has been called with some justice the "American language."

orders by at first charging 10 pounds of cinder, with 400 pounds of Lake Superior ore, and as no harm resulted from this homœopathic dose, his confidence increased gradually, as he slowly augmented the proportion of cinder, until, after several months of anxiety, doubt and fear, he arrived at what he regarded as an almost dangerous proportion,—40 pounds of cinder to 400 pounds of Lake ore. I believe this was the largest proportion of cinder used at that time, and recently I have been authoritatively informed that as soon as I had left the vicinity the use of cinder in the blast-furnace was discontinued, and it was thrown away as before. While I was engaged in experimental work with the oxy-hydrogen blowpipe, a circumstance occurred which is a fair illustration of the malicious character of the antagonistic feeling that existed in the community relative to the laboratory, and all that were connected with the new enterprise. One morning, on attempting to put the blowpipe in operation, to my surprise, after burning a short time the flame was extinguished; and, what astonished me still more, I could not relight it. On examination I found that the water-pipe had been disconnected, and a tightly-fitting wooden plug had been driven into it; the pipe had then been recoupled, so that to all appearance everything was in good working order. Whether the scoundrel who inserted that plug had simply mischief or murder in his heart has not yet been revealed. Soon after this occurrence, in the month of January, 1865, on my return from a short absence, I entered the laboratory only to find naked walls; everything removable had been taken away; not so much as a test-tube remained to show that chemical work had ever been done in the building. Herr Unkunde Unheilschwanger and kindred spirits had at last accomplished that for which they had so long labored. "Dufree's 'pothecary shop," as it had been derisively called, had ceased to exist.

At the act of vandalism which I have described, I manifested no surprise; of it I made no complaint; but then and there I mentally resolved that as soon as the first rail was rolled from steel made at Wyandotte, I would leave a community which had afforded me so many painful illustrations of the potential verity of the lines of Gray:

> "Where ignorance is bliss
> 'Tis folly to be wise."

The value of any particular mechanism or method of procedure may be fairly measured by the frequency of its use, and retrospectively contemplating the ever-increasing proportions of our siderur-

gical industries, reflecting upon the enormous aggregate of their present annual production, and remembering that these splendid results are but the crystallization of the intelligent thought of skilful men, from among our engineers, metallurgists and chemists, I find my justification for the chemical work undertaken at Wyandotte, in the fact, that to-day, in every well-ordered establishment for the manufacture of metals, the laboratory is considered an indispensable adjunct; and Science, represented by the engineer and chemist, stands at the right hand of Labor, advising, guiding, directing and controlling its every movement.

A SYSTEMATIC NOMENCLATURE FOR MINERALS.

BY H. M. HOWE, A.M., M.E., BOSTON, MASS.

It is a grave objection to the present system (or rather lack of system) of mineralogical nomenclature that, in the very great majority of cases, the name of a mineral gives no hint of its chemical composition, one might almost say no suggestion, however faint, of anything connected with it or characteristic of it, chemical, physical, historical, geographical, geological, or lithological. In becoming acquainted with a mineral, in addition to learning its composition and important characteristics, one must also learn a name wholly unconnected with any of them.

It has occurred to me that a system might be devised in which the name of each mineral should express at least an approximation to its ultimate composition. It is far easier to learn the names of most minerals than their compositions. Most of us are familiar with the names and appearance of many minerals, especially among the silicates, of whose compositions we have but a rough notion. It would be the aim of such a system to enable us, in making the one slight effort of learning the name of a mineral, by that same effort and involuntarily to learn its composition, which now requires an additional and a much greater effort.

I have worked out a system designed to meet this requirement, and its description occupies the remainder of this article.

Doubtless there are many devices on which could be based other systems fulfilling the requirement above set forth better than that about to be described does, and at the same time furnishing names

at once more euphonious and more readily distinguished from eac other than it does.

I do not bring it before you to urge its adoption, which is n even to be thought of, but to present the matter in a tangible an concrete shape; to show the advantages which this *kind of syste* offers, believing that its manifest faults belong to the individu system, rather than to the class of systems of which it is but one; an in the hope that it may contain useful suggestions, and may haste be it ever so slightly, the arrival of the day when we shall have clear and systematic mineralogical nomenclature.

The system I have elaborated is similar to that employed in worl on logic to express the form of the syllogism, by the formation c the syllables which compose its name. In it the name of each mir eral consists of as many syllables as the mineral has different com ponents; a mineral consisting, for instance, of two oxides and a acid has three syllables, one for each oxide and one for the aci Each syllable commences with one or two consonants, followe by one or more vowels, and it corresponds to and relates to one the constituents of the mineral. The consonants with which eac syllable commences, stand for and indicate the presence of son particular component; the vowels which follow indicate the nun ber of equivalents of that component which the mineral contains i its ultimate composition, and their state of oxidation. Thus, th mineral rhodocrosite, carbonate of manganese, would be Caumnaet The first syllable indicates the presence of one equivalent of ca bonic acid, the initial *C* indicating the element carbon, the secon vowel, *u*, that the carbon is in the condition of deutoxide, and th first vowel, *a*, that one equivalent of that deutoxide is present. S with the second syllable: the consonants *mn* indicate the presen of manganese, the second vowel, *e*, indicating that it is present a monoxide, and the first vowel, *a*, that one equivalent of that oxid is present.

Thus through all the mineral names in this system a consonan or a pair of consonants, indicates the presence of a certain elemer or base, etc., the first succeeding vowel the number of its equivalen present, and the second vowel (if any) its state of oxidation.

The only exceptions to this are the final *te* affixed to many nam for the sake of euphony, and to give them a uniform ending, an the letter *x*, whose use is explained beyond. I am not even clear th the final *te* would not better be omitted.

As may be seen in the above example of rhodocrosite, the symbo

different elements are here employed to represent these same elements. However, as some of these symbols contain vowels, which I reserve for indicating numbers of equivalents and states of oxidation, I replace each vowel in the symbols of these elements with the consonant which next follows that vowel in the alphabet. Thus, for Ag I employ *bg;* for Ti, *tj*.

In designating the number of equivalents,

A	stands for	1	WA	stands for	15
E	"	2	WE	"	20
I	"	3	WI	"	30
O	"	4	WO	"	50
U	"	6	WU	"	more than 50
Y	"	10			

Intermediate numbers are expressed by the vowel corresponding with the nearest number.

For simplicity, all compounds are reduced to their ultimate composition, and, when this contains fractions, it is reduced to the simplest set of whole numbers, preserving the proportion between the different components. In a few cases this proportion is slightly altered in order to have simple numbers.

The state of oxidation is indicated by the vowels as follows:

A	indicates a	hemioxide,	$\dot{\bar{R}}$
E	"	monoxide,	$\dot{R}$
I	"	monoxide with an equivalent of a sesquioxide,	$\dot{R}$, $\dddot{\bar{R}}$
O	"	sesquioxide,	$\dddot{\bar{R}}$
U	"	deutoxide,	$\ddot{R}$, $\ddot{Si}$, $\ddot{C}$
W	"	higher oxide than deutoxide.	

Since the metals of the alkalies and of the alkaline earths and aluminium have each a single state of oxidation, in which they almost exclusively occur (the only exceptions being their chlorides, bromides, iodides, and fluorides, altogether very few in number), it has been thought more simple, at least more desirable on account of making the names of the minerals shorter and more euphonious, to allow the symbol of each of these elements to represent not the presence of the element itself only, but its presence in its oxidized condition, thus dispensing with the second vowel otherwise needed to indicate the state of oxidation. To meet the few cases where these elements occur unoxidized (their chlorides, etc.), the letter *x* is placed after the vowel representing the number of equivalents present, to indicate that the element is not oxidized, as in flaccax, CaF.

In many minerals, while the total number of equivalents of a certain group of bases taken collectively is always the same, the proportion which these bases bear to each differs in different specimens

of the same mineral. To meet this case, the alkalies, when thus interchangeably occurring, are designated by the letter *g*, the alkaline earths by the letters *gr*, alumina and sesquioxide of iron by *dr*, and the protoxide bases in general by *d*. These letters are also used when the number of bases present is so great that words of excessive length would be produced if each base had a separate syllable. Thus, some of the rare minerals contain eight or even (as in the case of æschynite) ten elements besides oxygen.

Water and silica occur in such a host of minerals that it is thought justifiable to give them shorter symbols than this system, if rigidly carried out, would call for, and at the same time symbols easily pronounced, and therefore adapted for the beginning of the names of those minerals, whose other components have symbols beginning with two consonants difficult to pronounce at the beginning of a word, as *Mg* or *Pb*. The symbols *sl* for silica and *th* for water have been selected.

In Table I. are given the symbols employed in this system for the different elements, etc., and, in Table II., the names of several minerals, the first column giving the name as given in Dana's *System of Mineralogy*, the second column the formula of the mineral as given in that work, and the third the name in the system here described.

Fl is used for fluorine, to distinguish it from *ff*, the symbol of iron.

Co is used for lime, as *Cb*, which should strictly mean lime, is, in chemistry, the symbol of columbium.

For oxygen *r* is used, since *P*, which should strictly be used, is the symbol of phosphorus, and *q* is impracticable, on account of its requiring *u* to follow it.

Vr is employed for the uranium, since *V* is the symbol of vanadium.

I have prepared a list of ninety-six names of minerals under this system, which can be seen by any one who wishes. They were selected by taking every tenth, and in some cases every fifth, mineral in Dana's *System of Mineralogy*, edition of 1877.

In the case of many silicates, especially of the hydrated silicates, it was found difficult to create euphonious names, which should express the complete composition of the mineral, and many of those given are confessedly harsh and disagreeable.

The case of the hydrocarbons is very puzzling. Not only have we compounds in great number, with ultimate compositions closely alike, and differing by such slight amounts that it would seem utterly impossible to distinguish them by the system here described, but, in the case of the ethylenes, we have a group of substances of

absolutely identical ultimate composition. Two ways of meeting this case suggest themselves.

Either apply to these minerals their chemical names, or else the names corresponding with the system here described, distinguishing between minerals of identical or nearly identical composition by supplementing these names with the Greek letters, α, β, γ, etc.

Neither way is wholly satisfactory, and it must be admitted that the hydrocarbons are a stumbling-block.

The few minerals outside of the hydrocarbons which have identical compositions, can in general be distinguished by changing the order of the syllables. Thus, we may call calcite *ccacaute*, and aragonite *caucċate*.

In the case of the native metals, it seems best to retain their ordinary names, as "native copper," etc., which, of course, express their composition perfectly.

It will at once and very properly be objected that the names I have given are far less euphonious than those now employed. While I freely admit this, it must be remembered that the degree of harshness which appears here is not a necessary consequence of this kind of system; simply, my ingenuity has not been great enough to create pleasant and readily pronounceable names.

Whether any human ingenuity can invent, under this or a parallel system, a set of names which shall be agreeable, is an open question; but I freely admit that they must be less musical than those which the same effort of ingenuity could create unhampered by any rules. As a *tu quoque* argument, I may cite the following mineral names from Dana, which are not exactly dulcid: Wolchonskoite, Arfvedsonite, Freieslebenite, Hverlera, Homilchin, Bosjemanite, Chromophosphorkupferbleispath, Nertschinskite.

Again, it may be objected that some of the names in this system are confusingly alike. I believe that this can be remedied by ingenuity, and I doubt whether there is more similarity between the names I have given than between those in use.

It is to be remembered that the names are all of a new kind, and at first sight appear far more alike than they would, were one accustomed to this kind of name; just as all Chinamen, all Russians, all sheep, all Hebrew characters, indeed all minerals, look alike to one unaccustomed to them; while Russians find no more difficulty in distinguishing each other than we do, and we are told that a shepherd knows each sheep in his flock. The Chinaman at first finds all white men exactly alike, because the points which most naturally catch his eye are points in which all white men resemble

each other, and are unlike Chinamen, and he has not learned to look for the often very minute points in which we differ from each other.

Here are a few instances, in which the mineralogical names now employed resemble each other closely, without in general causing serious inconvenience or confusion.

Mineral Names from Dana, closely Resembling Each Other.

Dana prefers other names to those given here in parentheses, some of which are, indeed, obsolete, though many of them are in frequent use.

Stilbite,
Epistilbite,
Hypostilbite,
(Carphostilbite,)
Parastilbite,
(Sphærostilbite,)

Basalt,
(Basaltine,)
Basanite,
Bastite,
Bastonite,

Beckite,
Bechilite,

Alunogen,
Alunite,
Alum,
Alumian,
Aluminite,
(Aluminilite,)

Triplite,
Tripolite,
Triphylite,

Trolleite,
Troillite,

Baikalite,
Baikerite,
Baikerinite,

Berthierite,
(Berthierine,)

Berzelianite,
Berzeliite,
(Berzelite,)

Cryolite,
Chrysotile,
Chrysolite,
(Chryosophane,)
Chrysoprase,

(Cyclopeite,)
Cyclopite,

(Danaite,)
Danalite,

Dyscrasite,
(Dysclasite,)

Olivine,
Olevenite,

Paragonite,
Aragonite,

Pitticite,
Pittinite,

Gahnite,
Garnet,

Margarite,
Margarodite,
Margarophyllite,

Sericite,
(Cerasite,)
Cerinite,

(Sodaite,)
Sodalite,

Spartaite,
(Spartalite,)

	Praseolite,	Stibnite,
Uralite,	Prasilite,	(Stiblite,)
(Uranite,)		Stilbite,
Uraninite,	Pyrargillite,	
	Pyrargyrite,	Sylvite,
		Sylvanite,
	Pyrite,	
	Pyrrhite,	Tachydrite,
	Pyrrhotite,	Tachylite,
	Retinite,	
	Retinalite,	Thomaite,
	Retinellite,	Thomsonite,
		Thomsenolite,
	Rosite,	
	Roselite,	Torbanite,
		Torbernite,
		Trichite,
		Trachyte,
	Menaccate,	
Bismuth,	Melaconite,	
Bismite,	Melanolite,	
	Melanterite,	
Bismuthite,	Melanite,	
	Melonite,	
Bismuthinite,	Melinite,	
Bismuthaurite,	Mellilite,	
	Mellite,	
Humboldtine,	Azorite,	Gehlenite,
(Humboldtite,)	Azurite,	Galenite,
Humboldtilite,		
	Hydrophane,	
Anthosiderite,	Hydrophite,	Castellite,
Xanthosiderite,	(Hydrolite,)	Castillite,
Chalcocite,		Chileite,
Chalcodite,		Chilenite.
(Chalcolite,)		
Syenite,		
Cyanite,	Magnesite,	
Cyanolite,	Magnetite,	

In the index to Dana's *System of Mineralogy* are 16 names ending in phyllite, 14 in siderite; 14 begin with chal (of which 9 begin with chalco), and 39 begin with pyr, pyro, and pyrrho.

TABLE I.—SYMBOLS.

Elements, bases, etc., represented by the several consonants and pairs of consonants.

$\dddot{\bar{\mathrm{A}}}\mathrm{l}$ = Bl	Cu = Cv	$\dot{\mathrm{N}}\mathrm{H}_4$ = Nh	U = Vr
Ag = Bg	Fe = Ff	Ni = Nj	V = V
As = Bs	F = Fl	O = R	Zn = Zn
$\dot{\mathrm{B}}\mathrm{a}$ = Bb	Hg = Hg	P = P	$\dot{\mathrm{N}}\mathrm{a}$, $\dot{\mathrm{K}}$, NH_4 } = G
Bi = Bj	H = H	Pb = Pb	$\dot{\mathrm{B}}\mathrm{a}\dot{\mathrm{S}}\mathrm{r}$, $\dot{\mathrm{C}}\mathrm{a}\dot{\mathrm{M}}\mathrm{g}$ } = Gr
Br = Br	$\dot{\bar{\mathrm{H}}}$ = Th	S = S	$\dot{\mathrm{R}}$ = D
C = C	$\dot{\mathrm{K}}$ = K	Sb = Sb	$\ddot{\bar{\mathrm{R}}}$ = Dr
$\dot{\mathrm{C}}\mathrm{a}$ = Cc	$\dot{\mathrm{M}}\mathrm{g}$ = Mg	$\ddot{\mathrm{S}}\mathrm{i}$ = Sh	
Cl = Cl	Mn = Mn	$\dot{\mathrm{S}}\mathrm{r}$ = Sr	
Co = Cp	N = N	Te = Tf	
Cr = Cr	$\dot{\mathrm{N}}\mathrm{a}$ = Nb	Ti = Tj	

Numbers of equivalents of the several elements, bases, etc., denoted by the first vowel following a consonant.

A = 1	O = 4	WA = 15	WO = 50
E = 2	U = 6	WE = 20	WU = more than 50
I = 3	Y = 10	WI = 30	

States of oxidation of the elements denoted by the second vowel following a consonant (i. e., by a vowel separated by another vowel from the next preceding consonant).

A = a hemioxide, $\dot{\mathrm{R}}$.
E = a monoxide, $\dot{\mathrm{R}}$.
I = a monoxide with a sesquioxide, $\dot{\mathrm{R}}\ \ddot{\bar{\mathrm{R}}}$.
O = a sesquioxide, $\ddot{\bar{\mathrm{R}}}$.
U = a deutoxide, $\ddot{\mathrm{R}}$.
W = a higher oxide than a deutoxide.

The letter X denotes that the element whose presence is indicated by the next preceding consonant is not oxidized.

TABLE II.—MINERAL NAMES.

NATIVE ALLOYS.

Present Name.	*Symbols* after Dana.	*Name under System here described.*
Allemontite,	$\mathrm{SbAs_3}$	Sbabsite.

SULPHIDES, ARSENIDES, BISMUTHIDES, ETC.

Zorgite,	(PbCu)Se	Sfepbacvate.
Sphalerite,	ZnS	Saznate.
Hauerite,	$\mathrm{MnS^2}$	Semnate.
Gersdorffite,	$\mathrm{Ni(SAs)^2}$	Sabsanjate.
Pacite,	$\mathrm{Fe(\frac{1}{5}S + \frac{4}{5}As)^2}$	Seffobsute.
Pyrargyrite,	$\mathrm{3AgS + Sb^2S^3}$	Subjisbete.

CHLORIDES, IODIDES, AND FLUORIDES.

Calomel,	$\mathrm{Hg^2Cl}$	Clahgate.
Molysite,	$\mathrm{Fe^2Cl^3}$	Cliffete.
Fluorite,	CaF	Flaccax.

Oxides.

Zincite,	$\dot{Z}n$	Znete.
Braunite,	$2\dot{M}n^2\dddot{M}n + \dot{M}nSi$	Shamnoemniute.
Gummite,	$(\dddot{U}\dddot{F}e)\dot{H}^3$	Thiffaovraote.

Anhydrous Bisilicates.

Enstatite,	$\dot{M}g\ddot{S}i$	Shamgate.
Amphibole,	$\dot{R}\ddot{S}i$	Dashate.

Anhydrous Unisilicates.

Forsterite,	$\dot{M}g^2\dot{S}i$	Shamgete.
Grossularite,	$(\frac{1}{2}\dot{C}a^3 + \frac{1}{2}\dddot{A}l)^2\dot{S}i^3$	Blashiccite.
Bredbergite,	$(\frac{1}{2}(\frac{1}{2}\dot{C}a + \frac{1}{2}\dot{M}g)^3 + \frac{1}{2}\dddot{F}e)^2\dot{S}i^3$	Grishiffaote.
Lepidolite,	$(\dot{R}^3\dddot{R})^2\dot{S}i^3 + \frac{3}{2}Si$	Drashidote.
Ilvaite,	$(\frac{3}{5}\dot{R}^3 + \frac{2}{5}\dddot{F}e)^2\dot{S}i^3$	Doffaoshite.
Leucite,	$(\frac{1}{4}\dot{K}^3 + \frac{3}{4}\dddot{A}l)^2\ddot{S}i^3 + 3\dot{S}i$	Kablashote.

Anhydrous Subsilicates.

Chondrodite,	$\dot{M}g^8\ddot{S}i^3$	Shimgyate.
Titanite,	$(\frac{1}{2}\dot{C}a^3 + \frac{2}{3}\dot{T}i\frac{3}{2})\ddot{S}i$	Shaccatjaute.

Hydrous Silicates.

Picrosmine,	$\dot{M}g\ddot{S}i + \frac{1}{2}\dot{H}$	Thashemgete.
Collyrite,	$\dddot{A}l^2Si + 9\dot{H}$	Shablethwate.
Faujasite.	$(\frac{1}{2}\dot{C}a + \frac{1}{2}\dot{N}a)\dddot{A}l$, $4\frac{1}{2}$ Si, $9\dot{H}$	Shybleccanbash.
Brewsterite,	$(\frac{2}{3}\dot{S}r + \frac{1}{3}\dot{B}a)\dddot{A}l$, $6\dot{S}i$, $5\dot{H}$	Grablashuth.
Sepiolite,	$(\frac{1}{3}\dot{H} + \frac{2}{3}\dot{M}g)Si + \frac{1}{3}\dot{H}$	Shimgethete.
Deweylite,	$(\frac{1}{3}\dot{H} + \frac{2}{3}\dot{M}g)^2\ddot{S}i + \frac{4}{3}\dot{H}$	Thoshimgete.
Pholerite,	$\dddot{A}l^2\dot{S}i^3 + 4\dot{H}$	Blethoshite.
Oellacherite,	$(\frac{1}{3}(\frac{1}{2}\dot{H} + \frac{1}{2}\dot{R})^3 + \frac{2}{3}\dddot{A}l)^2\ddot{S}i^3$	Thishwadiblote.
Chloritoid,	$(\frac{1}{4}\dot{F}e^3 + \frac{3}{4}\dddot{A}l)^4Si^3 + 3\dot{H}$	Blaffaathashate.

Columbates.

Pyrochlure,	$\dot{R}^2\dddot{C}b$	Reacbawte.

Phosphates and Arsenates.

Triplite,	$(\dot{F}e\dot{M}n)^3\dddot{P} + RF$	Dopawfate.
Adamite,	$\dot{Z}n^3\dddot{A} + \dot{Z}n\dot{H}$	Thazniebsawte.
Calcioferrite,	$(\dddot{F}e\dot{C}a^3)\dddot{P} + \frac{1}{4}\dddot{R}\dot{H}^3 + 4\dot{H}$	Pawdracbithote.

Nitrates.

Nitre,	$\dot{K}\dddot{N}$	Kanawte.

Borates.

Bechilite,	$(\frac{1}{2}\dot{C}a + \frac{1}{2}\dot{H})\dddot{B} + 1\frac{1}{2}\dot{H}$	Bewccathote.

Tungstates, Vanadates, Etc.

Descloizite,	$\dot{P}b^2\dddot{V}$	Vawpbeete.

Sulphates, Chromates, Tellurates.

Barite,	$\dot{B}a\dddot{S}$	Sawblate.
Glauberite,	$(\frac{1}{2}\dot{N}a + \frac{1}{2}\dot{C}a)\dddot{S}$	Sewnbaccate.
Uraconite,	$\dddot{U}^3\dddot{S} + 4\frac{2}{3}\dot{H}$	Thovriosawpe.

CARBONATES.

Pistomesite, . .	$(\frac{1}{2}\dot{\mathrm{M}}\mathrm{g} + \frac{1}{2}\dot{\mathrm{F}}\mathrm{e})\ddot{\mathrm{C}}$	Ceumgaffaete.
Hydromagnesite, .	$\dot{\mathrm{M}}\mathrm{g}\ddot{\mathrm{C}} + \frac{1}{3}\dot{\mathrm{M}}\mathrm{g}\dot{\mathrm{H}} + \dot{\mathrm{H}}$ . . .	Thomgociute.

HYDROCARBONS.

Heptylic hydrid, .	$\text{Ɵ}_7\mathrm{H}_{16}$	Cuhwate.
Ozocerite and other ethylenes, . .	$\text{Ɵ}_n\mathrm{H}_{2n}$	Cahete.

DISCUSSION.

DR. EGLESTON: I do not think anybody can help but admire the great ingenuity of this system proposed by Mr. Howe. I do not say that it is not practicable, but it appears to me to be a wrong system to *teach* mineralogy *to students.*

It has been my misfortune to have learned the science of mineralogy several times. I commenced by learning that sulphate of baryta was the name of a mineral. It was then called barites, then baryte, which changes are quite simple, but with many minerals the changes of name were so dissimilar that even now they sometimes come up to trouble me on days that are dark and damp and things are not going right. The whole trouble is that we begin by teaching students, or teaching ourselves, only one thing at a time, and everything else to be learned about a mineral must be remembered by an additional effort of memory. If we who are practicing in any part of the profession of mining engineering, which is so manifold, were to attempt to learn never more than a few characteristics of what we were studying at once, I do not know that we would ever get through,—we would certainly not accomplish as much as if we learned at once a larger number of facts. It is not difficult to learn that baryte is sulphate of baryta, that it is orthorhombic and not easily fusible, and that it is insoluble, as it is to learn baryte. The first effort of the memory is perhaps a little more difficult than to remember the name, but that effort having once been made, the substance is definitely known, and all of these facts suggest themselves at once with the name. The number of mineral substances studied in the science of mineralogy is fully eight hundred. We require to use something over two hundred of them. We would get but a limited knowledge of the science if we learned but one thing at a time about all these. Of course a certain amount of eye experience has to be associated with the ability to remember so many things learned at once. I have been teaching mineralogy

for twenty-one years, and when I commenced I thought I should never be able to make the students learn sufficient to pass a reasonable examination. I commenced to use this method from necessity about fifteen years ago, and last year by using the system which I have explained, with the collections all packed up, with a room so dark that we could not see on an ordinarily dark day and only imperfectly on a bright day, with every other condition unfavorable, I had some of the best examinations that I have ever had. The reason being, that when I gave a mineral to a student for the first time, I not only named it to him, but told him that it represented a certain chemical composition and certain physical peculiarities, and that when he saw the mineral it ought to recall to him all of these different properties. It is certainly true that disconnected and isolated things, things not connected in any way with any association of ideas, are very difficult to remember, but when a group of facts is considered it is not so, for each fact plays in some degree the part of a help to remember the others.

I do not say that this method of Mr. Howe's may not take the place of the present method of mineral nomenclature, that of course is impossible to say, but I think there is a defect in it, and that this is the defect of all systems of artificial memory, and that is, that at the time when the artificial memory is to be used the thing upon which the system is based is forgotten. I should much rather rely upon the intelligence of a person to remember four or five or six characteristics of a substance at once than to try and retain a large number of artificial points, which will go from you just at the time you want them most. We commence by requiring the student to learn the name of the mineral, its composition, fusibility, solubility, and hardness. I think that a system which appeals to the intelligence will in all respects stand a better chance of success than one which appeals to an artificial memory. As Mr. Howe says, some of his names strike us at first as non-euphonious, but I do not know that they are, and at any rate I would not oppose the system on that account as strongly as because it is founded on artificial memory.

Dr. Frazer, Philadelphia: The remarks of Dr. Egleston on the subject of mnemonics reminded me of the same objection which I saw wittily alluded to some years ago in the preface to Flavel Gouraud's book. One objection he says to the use of mnemonics is, that one must remember a whole system, and then remember the thing besides. The same kind of reasoning could be applied to the use of a wheelbarrow. One might say that it was absurd for a man

to move a two-hundred-pound trunk on a wheelbarrow because he adds the weight of the wheelbarrow to that of the trunk.

I do not believe that the objection of non-euphony is very serious. These new names do look barbarous, but then there are a great many barbarous names in mineralogy. If Breithaupt's idea of nomenclature had been carried out, it seems to me it would have been the perfection of a system. He earnestly labored for a systematic nomenclature, and commenced by demanding and pleading for a somewhat similar system to that of botany. He protested above all things against the giving of the name of any man to a mineral, but this vicious habit grew so rapidly that at last even Breithaupt himself contracted it. A plan for naming is, in the first place, to study the mineral and find whether it has a peculiar physical property, or any kind of property, which is characteristic of it, and then let us give it a name, not connected with the name of the man who discovered it, or the name of the patron of the man who discovered it, but a name which shall describe that peculiarity. But I think it is a mistake to base the names given to substances upon their chemical composition, because these are qualities which cannot be made useful in determination. Besides, it is very often found that most important chemical peculiarities are overlooked in the first determination of the mineral, as, for example, the lithia in some of the micas of the great Werner collection in Freiberg.

I think that in mineralogy we ought to step a little outside the line of chemical theory, and to designate the mineral, select that quality which is most striking, as nearly as we can get at it; and if we find that it is of a family in which another quality is more striking, it ought to be sufficient reason for employing its characteristic to distinguish it from other members of the same family. If the chemical properties of a mineral were always the most striking and the most needful to be known, this would be a capital system; but I assert here and now that I do not believe that chemistry is the best basis for mineral nomenclature, and I do not think that if mineralogy had been simply a branch of chemistry it would have become so important a part of the training of a field investigator.

Mr. Howe: Professor Egleston thinks it is just as easy to learn six things about baryte—that it is sulphate of baryta, orthorhombic, not easily fusible, insoluble, decrepitating, and heavy—as to learn one of them only, that it is sulphate of baryta. The whole, then, is no greater than one of its parts? No; it is harder, much harder,

to learn six things about a substance than one of those six, but it is easier to learn the six at once than at six different times.

He objects to this kind of system because it is an artificial aid to the memory; this is not a valid objection. Crutches and locomotives and horse-cars are artificial aids to locomotion, the first undesirable for those who can dispense with them, the others very desirable. The convalescent should not avoidably prolong the use of his crutches, because the slight temporary convenience they afford is more than counterbalanced by the disadvantage they entail, preventing the proper use of the muscles, and thus retarding the recovery of their strength. So relying on locomotives or horses undoubtedly tends less to enduring pedestrianism than does a total reliance on one's own legs. Of two men whose business compelled frequent journeys from Washington to Philadelphia, the one who habitually made the journey on foot would have, in the event of a total stoppage of railway travel by a strike, accompanied by a complete disablement of horses by an epizootic disease, a measurable advantage over the other who ordinarily travelled by rail. Nevertheless, locomotives are desirable though artificial aids, because the saving of time and energy which they effect for things more important than chronic perambulation more than counterbalances the disadvantages their use is liable to entail at remote intervals and under conditions unlikely to arise.

So an artificial aid to memory is desirable or undesirable according as its advantages counterbalance or are outweighed by its drawbacks. To a certain extent every systematic nomenclature is an artificial aid to memory. Every system of whatsoever kind is an artificial aid to something, nor is its being artificial a reproach to it. You number or alphabeticize your streets and houses because it is easier to remember and find the location of a numbered street or house.

Our chemical nomenclature is a case in point. It is an artificial aid to memory. Its distinctions, by means of adjectives ending in *ic* (as ferric) as opposed to those ending in *ous* (as ferrous): by prefixing Greek and Latin numerals to denote multiplication of positive and negative ingredients respectively, are purely arbitrary and artificial. They are indisputably advantageous nevertheless, because their convenience and clearness far outweigh any possible confusion which might arise on forgetting them. No sane man would propose abandoning them for a barbarous chaos of names like that of our mineral nomenclature.

A systematic mineral nomenclature we should have. When it comes it will be an artificial aid to memory, and when it has become generally used, the idea of reverting to the present nomenclature would appear as ridiculous as it would now seem to abandon our chemical nomenclature for a similar chaotic slough of names.

A systematic nomenclature should be clear, concise, and founded on an important and convenient classification. If it is based on a plan complex, confusing, and very liable to be forgotten, this will be a serious fault. If its use, like that of crutches, tends to induce such a reliance on it that, in the event of forgetting it, one is much worse off than if he had never used it, that too is a serious fault. Now it must be decided for each particular system whether its drawbacks outweigh its advantages or not.

Now in chemical nomenclature its clearness, conciseness, and the paramount importance of the distinctions on which it is based immensely outweigh the trifling disadvantages under which one who had relied on it and forgotten it would be placed compared with one who had never used any systematic nomenclature at all, but had retained, say the alchemistic names, fixing by effort of memory the composition of each substance in his mind.

Of two youths of exactly equal mental powers, one calls a certain red substance colcothar; the other calls it ferric oxide. While walking they meet this substance; both have forgotten its name. Will the one who called it ferric oxide be appreciably less likely to recall its composition than the other? I think not. Or suppose both remember their names for it, but the one who calls it ferric oxide forgets what ferric means. Will he be sensibly less likely to remember its composition than his friend? I think not.

Nor do I believe that a person who used a systematic nomenclature for minerals similar to that I have described would be appreciably less likely to remember the composition of a mineral, if he forgot the plan of that system, than another person who used the present senseless chaos of names, while if the former remembered the plan of his system he would have a distinct advantage over the other.

If I am right, then, objecting to it because you may forget it just when you want it is like objecting to locomotives because just when you want them they may break down; the fact of having employed them will be no sensible disadvantage if they do break down.

Now it may be that I have attempted to make my system do too much, and have thus made it too complex and too liable to be forgotten. This, however, is a fault of this particular system, which I

do not advocate, but merely expose for illustration, and not a fault of this class of systems.

I think no serious fault can be found on account of lack of clearness and conciseness.

As regards the classification on which it is based, chemical composition, I cannot agree with my critics. I believe that chemical composition, in nine cases out of ten, is the most important thing to know about a mineral, and, moreover, it is far easier to infer other important qualities from chemical composition than the converse. To the chemist, the metallurgist, and the miner it is indisputably the most important. It is of the greatest moment to the lithologist, the mineralogist, and the geologist. For instance, what one thing can throw so much light as chemical composition can on the all-important questions of the genesis of minerals, of ore deposits, indeed of all deposits?

We do not need to be told by the name of a mineral that it is hard, heavy, or white. I see and recognize a mineral; my eye tells me whether it is white or blue, my knife whether it is hard or soft, my hand whether it is light or heavy; let the name tell me what I cannot otherwise find out, unless I have Dana or Brush at hand, what its composition is.

Dr. Frazer: I think that Mr. Howe forgets in that statement that the very fact that it is easy to determine these characters makes their expression in the name a most important aid. You may have a number of minerals that look just alike, but one will be remarkable for one characteristic and one for another. The connection, the important characteristic with the name, aids the memory and leads to the close observation of other qualities.

I plead that the important characteristic to the geologist is not the chemical composition because it never can be verified in the field. He wants to know, first, whether this mineral is heavy, hard, brittle, etc., and after he knows these things its chemical constitution is known through the labors of previous chemists. But in any case chemical analysis can then follow and give the mineral its accurate place.

Mr. Howe: I see that we are at cross-purposes. You look at the question from the standpoint of a man who seeks to recognize or identify an unrecognized mineral. I look at it from the standpoint of one who wishes to know the composition of a mineral already recognized. It is an open question whether a nomenclature can be made most useful as an aid to recognizing minerals or as an

assistance to remembering the composition of those already recognized. I am inclined to think that the latter is the most useful and effective field for it, for it is to be remembered that while a name indicating composition would denote *positively* the composition of a known mineral, a name corresponding with some prominent and easily recognized characteristic would aid *but faintly* in recognizing a mineral. We recognize a man with a large nose whom we have not seen for years just as easily if named Jones as Rhinbeak, though the latter name might be more easily recalled after the recognition had taken place. The fact that kyanos means blue does not help us materially to recognize cyanite, though it indeed helps us to remember its name after recognizing it, which is quite a different thing.

DR. EGLESTON: There are a great many minerals in which, when viewed from an optical standpoint, and often in minerals without industrial works, the chemical composition is the most insignificant characteristic of the mineral. We are obliged to remember it, and do remember it, because we are brought up to remember it, but I can think now of a number of minerals in which the part that is least desirable to know, or the part which from a scientific point of view is least important, is the chemical composition. If we regard the practical application from an industrial point of view, the composition is evidently the most important characteristic. In practical work, the very first thing a person determining a mineral does is to take out his penknife, and if that does not give the indication, he waits until he gets a blowpipe. It is the physical characteristics that determine it for him, and the chemical composition then settles its industrial value. With regard to euphony I don't see why, after we have learned to pronounce it, one name should not be just as euphonious as another. I must say that the name Wolchonskoite shocked me a little, and I should much prefer something a little more euphonious, but the mere matter of euphony has nothing to do with the question. Such names as Mr. Howe's would be no more barbarous after we had got used to them than the present ones are now.

THE BESSEMER PLANT OF THE NORTH CHICAGO ROLLING MILL COMPANY AT SOUTH CHICAGO.

BY ROBERT FORSYTH, CHICAGO, ILL.

As the latest plant on a large scale, the new Bessemer works of the North Chicago Rolling Mill Company, at South Chicago, presents some features of interest to steel-makers, I have ventured to lay before the Institute a short description of that plant, and some remarks upon the practice there.

At the time the South Chicago works were designed the adoption of the basic process in this country seemed imminent. Experience in Europe had demonstrated the perfect success of the process technically, and the question of its commercial value was one which, for any particular works, would have to be settled by its special advantages for procuring the necessary ores and basic materials. Under the circumstances, it was thought best at South Chicago to so arrange the plant as to allow the introduction of the basic whenever it became advisable, and to make such other changes from the standard type of Bessemer plant as the state of the art seemed to demand and to foreshadow. As the use of metal direct from the blast furnace, while generally condemned by experts here, was in such successful practice in Europe (particularly in connection with the basic process), there was no doubt about its feasibility, while its economy in fuel and labor made it especially attractive to the Western manufacturer. It was accordingly decided to build a direct-metal plant adapted to the basic process.

The ingots made were to be rolled into rails at one heat, and were to be of such size (12 inches square and long enough for three and four rails) as to be readily and quickly handled by the rolling machinery proposed. This small size of ingots, and the large number cast from each heat of 10 tons, made it necessary to provide a good deal of room in the casting-pit—much more than in any previous plant—and to put down extra facilities for handling ingots. To meet the delays incident to the basic process—to insure that one vessel should be always blowing if necessary, and to provide opportunity for current repairs to linings, etc.—it was decided that three vessels should be used, and, to properly concentrate the work of

handling ingots and moulds, these vessels were to work to one casting-pit. Mr. Holley had just brought out his plan of removing vessel-shells bodily from their supports, and the adoption of this plan was resolved upon as furnishing the best solution of the basic lining difficulty and allowing a neat and convenient form of vessel supports. The plan involves the conveyance of the old vessel-shell to a convenient repair-shop and the substitution of a newly-lined shell in its place, and the proper disposition of these shells and of the vessel-bottoms and iron and steel-ladles (all of which are obviously out of place in the converting-room proper when not actually in use), was a matter of no small difficulty. Circumstances compelled the construction of the repair-shop in the form shown (see accompanying Plate), which, though not perhaps the best possible, yet answers the purpose very well, so far as it has been used.

The difficulty of working three vessels to one casting-pit without the use of cumbrous and unwieldy ladle-cranes was got over by the method of transferring the steel ladle from receiving cranes to the casting crane. This plan, which is due to the suggestion of Mr. L. G. Laureau, was by him worked out for a pair of vessels, and is shown on Mr. Holley's latest design for a 10-ton two-vessel plant. As used at South Chicago, it was modified for three vessels, and the simple but important change was made of putting between the jibs of the cranes a short piece of fixed track on which the ladle may rest in its transit from crane to crane. This perfectly safe, simple, and practicable method of ladle-transfer is really an important step in Bessemer construction, and will lead to some changes in design of plant. The same object is attained in some foreign works by pouring the charge of steel from one ladle to another—a plan which consumes more time than the transfer and involves the cooling of the metal. The use of the transfer-ladle, moreover, permits the iron and spiegel ladles to be brought in front of the vessels instead of behind them, thus simplifying construction and allowing the use of very short runners, or none at all. It will thus be seen that several novelties of construction were in this plant introduced for the first time, and that it stands alone in this country as a plant built expressly for direct-metal and the basic process.

The site of the works is a sand-beach washed up by Lake Michigan, and ranging in height from 6 inches to 3 feet above mean lake level. It is useless to dig in this material, which, as soon as water is reached, becomes a tolerably firm but strongly soaked sand; so

the foundations, with one exception, were begun just below water level by a layer of concrete, upon which the stonework was laid. The general level of the works was established at 10 feet 6 inches above lake-level, and all the building-foundations were carried up to this height, securing ample head-room in sewers and good drainage. The foundations for the very heavy lifts under the vessels were begun at 20 feet below general level, or 9 feet 6 inches below the lake; and these excavations were made inside sheet-iron cylinders, open at both ends, and sunk by digging under their edges and weighting them. When the cylinders were in place a thick bed of concrete was laid in them, upon which the stonework was begun. Great care was taken in proportioning the foundations to the weight resting upon them, and, though laid upon such apparently poor bottom, they have stood well and settled evenly. Ground was broken on April 12th, 1881, and construction occupied fourteen months, the first blow having been made June 15th, 1882.

As there was plenty of room on the ground in most directions, the parts of the plant were separated so as to secure good light and air, and the buildings accordingly are: A boiler-house, 118 feet by 44 feet; engine-house, 114 feet by 48 feet; converting building, 108 feet 6 inches by 102 feet 6 inches, to which adjoin a special cupola building, 66 feet by 47 feet, and a shed behind the vessels, 102 feet 6 inches by 22 feet; repair shop, 238 feet by 75 feet, to which adjoins a ladle drying-shed, 44 feet by 75 feet; producer-house, 60 feet by 44 feet; and a grinding-house, 100 feet by 50 feet, besides the necessary sheds for storing refractory materials, etc.

The ground area covered by buildings is about 60,000 square feet. The engine-house contains two separate horizontal condensing blowing engines, with steam cylinders 54 inches in diameter, and air cylinders 66 inches in diameter by 60 inches stroke. These engines were designed by Mr. Kreite, the company's chief engineer, upon the plan of those which had done good service in the North Chicago plant for ten years. The pressure-pumps, two in number, are Worthington compound pumps of the largest size, and have given excellent results. In the engine-house are also the necessary feed and tank-pumps, accumulators, heaters, etc. The converting-building contains three 10-ton vessels, two receiving ladle cranes, one casting-ladle crane, three ingot-cranes, and one crane used in cleaning and handling ladles. The ingot and ladle-handling cranes are placed symmetrically about a casting-pit of 20 feet radius, and command

its whole circumference. In this pit there is room for forty 12-inch moulds, occupying nearly three-quarters of the available casting space, and there is an ingot-crane for each set of moulds, so that three heats may be working at the same time if necessary. Ladle-cleaning and removal of slag, etc., are done at one side of the pit, new ladles and vessel bottoms are brought in from behind the vessels, and vessel-slag goes out in the same direction, leaving a clear and unobstructed space around the pit, which is devoted to its proper use, the handling of moulds and ingots. Under and behind the vessels the floor is at general level, while the space around the pit, comprising the working-floor of the converting-house, is 3 feet above general level. The ingot-cranes have a stroke of 11 feet, sufficient to strip the moulds from the ingots and set them upright on cars, which are then taken out of doors. This practice, which is now very general, greatly relieves the men about the pit, and is of special importance in the case of long and narrow moulds.

The three 10-ton vessels stand with their trunnion-axes in the same line, 18 feet above general level, and are 26 feet apart from centre to centre. They are of the old form (not concentric), 10 feet in diameter outside the shell, and have no stacks, but blow out of doors through arches in the end wall. Slag and sloppings from the vessels fall upon a nearly flat roof which covers the standing hydraulic cylinders, etc., in rear of the vessels. Each vessel has a cast-iron trunnion-section in one piece, inside of which is hung the shell, or vessel proper, which can thus be removed on the plan proposed by Holley. The vessels are rotated by horizontal hydraulic cylinders 20 inches in diameter, with racks and pinions of cast-iron. Steel would perhaps have been stronger, but the expense seems hardly warranted for horizontal cylinders, in which that prolific source of broken racks, the drainage of water from one side of the piston, owing to a leaky pipe, can be completely guarded against by taking the water into the cylinder on the upper side, instead of the lower, as is usual. The vessels turn through an arc of 270°, and move with great smoothness and steadiness. Under each vessel is placed a hydraulic lift for handling the vessel shell and putting on bottoms, with a plunger 24 inches in diameter, a stroke of 8 feet, and a platform 12 feet square. Although a shell has never been handled in this way, yet from the experience with the apparatus, I entertain no doubt of the perfect practicability of the method, and look to see it adopted as soon as the basic process shall have come into use. One of these lifts was found to have a net lifting-capacity

of 98,000 pounds, at 300 pounds pressure on the accumulator, and this pressure, less weight of bottom and car, is exerted on the joint between bottom and vessel when a new bottom is put on.

In front of the vessels, and 19 feet above general level, runs the elevated railway on which metal and spiegel are brought—the one from the blast-furnace, the other from the spiegel-cupola building adjoining the converting-room, which contains, besides the four cupolas, the necessary blowing machinery, scales, and two hydraulic elevators to serve the cupolas, and also to raise basic and other material to the vessel floor. The scales and tracks in this building are so arranged that, if necessary, any cupola may be melting siliceous pig while one or more of the others may be melting spiegel. Wide runways to the elevators are provided for transportation to the vessels of scrap and basic additions, and space is left for a furnace for heating ferro-manganese, while a blacksmith's fire and steam hammer for drawing out test ingots are conveniently placed on the lower floor. The metal is brought from the blast furnaces, a distance of 1500 feet, in 10-ton ladles, mounted on cars, up an incline with an average rise of 2 feet per 100, to a level siding just outside the converting building. From this siding, which is carried on arches, the space beneath which is utilized for a stopper-room and oven, storehouse, etc., the ladle car is pulled by a special locomotive into the building, and the metal is poured into a short runner directly in front of the vessel. Melted spiegel is brought in the same way from the opposite side of the building. Rapid and convenient transportation of melted metal, and the least possible waste of metal in the form of runner-scrap, are the important points secured by this arrangement. Ample floor space is provided around and beneath the vessels, and, in fact, all over the plant, and the numerous door and window openings, and the absence of stacks, make the neighborhood of the vessels, which is usually unbearably hot, as comfortable as any part of the plant.

In front of the vessels are the two ladle-cranes, so placed that both of them may serve the centre vessel of the three, while the end vessels are reached by one crane each. As the operation of these ladle-cranes and the ladle-manipulations generally are distinctive features of this plant, I shall describe them in some detail. The ladle, placed on one of the receiving-cranes, having been filled with steel from the vessel, the crane (which is of the ordinary ladle-crane type, with fixed jibs and hydraulic traversing cylinder) is swung

round until it points to the centre of the casting-pit, some 40 feet distant. In this position the crane is lowered, and when the plunger touches the bottom of the cylinder the outer ends of the jibs rest solidly upon iron blocks which carry one end of a piece of fixed track, some 10 feet long, placed in line with the crane-jibs. The other end of this track is carried upon similar blocks, upon which the jibs of the casting-crane rest when lowered in the same way. These blocks have sloping sides, and the ends of the jibs carry rollers, which, touching the sides, will gently guide the jibs into position if they are first brought within a foot either way of their proper place. The receiving-crane having settled into its position, the carriage and ladle are pushed off the jibs by the traversing cylinder on to the track, and pulled by the traversing cylinder of the casting-crane off the track and on to its jibs, when the crane is raised and swung round for casting. The whole transfer occupies less time than the description, and is done with perfect smoothness and safety.

As regards the transfer of the loaded ladle, the track between the cranes has advantages over the plan of bringing the crane-jibs together, in that it admits of adjustment, both vertically and horizontally, to suit variations in the position of the crane-jibs due to wear of top supports, elasticity of materials, and slight derangements of any sort, and it permits the removal of the casting-pit to any desired distance from the vessels. There are other advantages which I shall refer to. After casting, the ladle-crane is swung round to one side of the pit, and lowered upon a set of blocks as before, and the ladle and the carriage are pushed off upon a track similar to those between the cranes, where the stopper is removed, and the ladle cleaned in the usual manner, the slag being dumped in a pan, which is afterward hoisted out by a crane. This cleaning being done, not on the crane in the usual way, but on a separate track, the casting-crane is left free to take from a receiving-crane another ladle filled with steel and to proceed at once with casting, and the first ladle, having been cleaned, is picked up with its carriage and placed upon one of the tracks between the cranes ready for another charge. Two ladles are thus kept in constant use, and casting of ingots may go on almost without interruption—a point of a good deal of importance when the time required for proper casting of 10 tons of steel into 12-inch ingots is considered. The great blowing-capacity of the vessels is thus fully utilized, and quantity of product becomes

a question of keeping the pit clear of ingots. Iron and steel ladles are lined and patched in the repair-shop, a special crane being there provided to handle them, and new steel-ladles are brought into the converting-room, and the slagged ones removed at once by a locomotive, which performs the same service in the case of bottoms and slag cars. Thus, so far as possible, all work of repair and renewal is taken out of the converting-room and done in a more convenient and economical way in a place specially provided. A newly-lined ladle is placed at once under a gas-firing hood in the drying-shed, where there are twelve hoods, with tracks and turn-tables, and dried and heated by a perfectly controllable apparatus without any nuisance of smoke or ashes. The iron-ladles may be more conveniently made up and heated in the immediate neighborhood of the blast-furnaces, where furnace-gas and blast are always available, but the local conditions at South Chicago did not favor this plan.

The repair-shop, in which not only the ladle repairing, but also the vessel-bottom work, is done, is a building 238 x 75 feet, back of the converting building, and separated from it by an alley 20 feet wide. Its great length is due to the necessities of the site, part of which was under water when construction began, and to the fact that the only line of rails bringing supplies other than stock to the blast-furnaces, and pig iron from them, was made to pass between the building and the shore of the lake. The north end of the house is devoted to vessel-bottoms, and contains twelve gas-fired drying hoods, a turn-table and hydraulic crane. The bottoms are of the "dish" pattern, and each bottom stands on a car, which it never leaves except to go on a vessel, and is made up with three or four wooden tuyere-dummies, which are knocked out when the bottom is finished. The car and bottom are now run under a gas-hood, the gas and air turned on, and the flame playing over the top surface of the bottom is drawn down the holes left by the withdrawal of the dummies, through the tuyere-box and a drum hanging in the car frame into an underground flue leading to a chimney. In this way the bottom-stuff is thoroughly dried (burned, if necessary) without first heating and cracking the castings of the bottom and the car, as is the case in ordinary oven-practice, and the heat may be adjusted to the requirements of each bottom, a gentle flame being put on at first and increased afterward as the bottom dries. This plan will, I think, be found especially adapted to basic bottoms. The dried bottom is pulled from under the hood by a locomotive and taken to the vessel, when car and bottom together are raised by the hydraulic

lift and the bottom is keyed on. The joint between bottom and vessel is perfectly flat, and the joint-stuff is subjected by the action of the lift to a pressure of about 2000 pounds per square foot, which it is hardly necessary to say secures a good joint—indeed, leaky joints are unknown. An old bottom, when removed from the vessel, is placed over a pit, tuyere-stumps and loose stuff knocked out, and is side-tracked for making up. With ordinary life of bottoms, all making up is done on the day-shift.

The centre of the repair-shop is taken up by tracks for transportation of bottoms, slag, etc., to and from the vessels, and by the (proposed) tracks for moving the vessel-shells when that shall be attempted. An arched opening 40 feet wide in the side-wall is left for the accommodation of a turn-table half in and half out of the building, and from the three vessels tracks of 10-feet gauge converge to the turn-table, which will distribute the vessel-shells to positions convenient for repair and renewal of linings. None of this work has yet been put in, but the provision for it very much increased the dimensions of the repair-shop, which, for a plant in which removal of vessel-shells is not intended, can be better arranged. The gas-flue for conveying gas to bottom and ladle-hoods is hung on brackets from the walls, as is also the blast-pipe supplying air to the hoods, which leads from the Sturtevant fans in the spiegel-cupola building. There is a gas-fired oven for drying clay, etc., and a producer-house containing eight gas-producers of the old Siemens type completes the range of buildings connected with the repair-shop.

The repair-shop idea—the separation, so far as possible, of repair and renewal of refractory materials from the actual operations of the plant—was a favorite idea of Mr. Holley's, and the results of its application so far have amply justified his expectations. Gas-heating of bottoms and ladles—more completely carried out, perhaps, in this plant than in any other—has been very satisfactory. The cost, per ton of ingots, of fuel for this purpose will not exceed that of the coke, or equivalent fuel, burned in ovens in the usual way, while the greater cleanliness and convenience of gas burned in hoods, as described, leaves nothing to be desired.

The machinery of the plant throughout is solid and strong. The blowing-engines are, I believe, the largest in this country ; they are certainly of ample capacity, and work smoothly and well, and every effort was made in the design of the hydraulic machinery to secure rapidity and certainty of action, as well as strength, durability, and

accessibility for repairs. All pipes to and from hydraulic cylinders are large, and as short and straight as possible, and every pipe about the place is laid in a sewer, and can be followed throughout its whole length. Particular attention was given to the strength of ladle and ingot-cranes, and to their foundations, and the ingot-cranes, it is believed, are the largest and strongest yet built, while the ladle-cranes have performed their exceedingly heavy work in a very satisfactory manner.

The vessels and bottoms were designed for working heavy charges of direct metal, and, having in view the possible occurrence of "long blows"—those curious phenomena by which the blast-furnace people remind us how perfect their control of the blast-furnace is—care was taken to provide plenty of wind, so far as large blast-pipes and tüyere-area will do it. There are eighteen tuyeres in the bottom, the blast-pipe on the vessel is 12 inches in diameter, and the blast-main is a 15-inch pipe. These sizes seem to be sufficient, for, on trial, it was found that with a pressure of 26 pounds at the regulating valve there was 25 pounds in the tuyere-box during the first five minutes of the blow; 22 pounds at the valve gave 20 pounds in the tuyere-box during the next seven minutes; and during the drop of the flame the pressure fell to 20 pounds at the valve, with 17 pounds in the tuyere-box. This sudden fall of pressure at the end of the blow is probably due to release of back-pressure in the vessel when carbonic oxide ceases to be evolved, and it points to the necessity of ample engine-power for working the basic with its several minutes of over-blow.

The longest blow on record at South Chicago lasted forty-five minutes, but 10 tons of metal with 2 per cent. of silicon is commonly blown in ten to twelve minutes, and one blow of 9000 pounds was finished in three minutes. At the rate of twelve minutes to a blow, five heats an hour can be made regularly, for with three vessels blowing can go on continually, and by the use of two ladles and the transfer-cranes, as described, a ladle is always ready for a charge when finished.

As this rate of working will keep the vessels constantly employed, an easy arithmetical process brings us to that for which we long have sought—a possible limit to the product of a Bessemer pit, viz., the respectable figure of 600 tons in twelve hours.

The general appearance of the plant is striking and unlike that of any other in this country—nor, indeed, is there a plant which much resembles it anywhere. Placing the vessels in the end of the

converting-building, and bringing metal and spiegel to them in front and from opposite sides, does away with the gloomy cave which, in the old style of plant, exists behind the vessels, and in which some of the hardest and hottest work has to be done. The elevated railway, crossing the building at a height securing good head-room beneath it, supports, partly, the platform about the vessels and allows this platform to be, not a cramped and narrow staging just large enough to carry runners, but a roomy floor extending all round and behind the vessels, affording ample space for all manipulations and greatly increasing the comfort of the workmen. Short and straight runners reduce runner-scrap to a minimum and get metal to the vessels with the least possible delay. Removing the pit, with its heavy and constant work, away from the vessels is a great improvement, and takes away much of the danger from slopping of metal to which pit-men are exposed. It has happened, owing to sudden failure of the water-supply, that a vessel with a heat in it has turned over, depositing the metal, not in the pit among the men working there, but upon the floor on the general level and upon the platform of the large hydraulic lift, which, it may be of interest to note, was not in the least injured. A few minutes' work sufficed to break up the mess and get it out of doors. This, by the way, is the only accident which has occurred to the hydraulic apparatus, and it arose from the failure of a suction-pipe bringing water to the pressure-pumps. In the course of twelve months' working not a pipe has burst nor a joint given out—a somewhat remarkable record.

Removal of slag, so important in basic working, is provided for by tracks upon which cars may be run under the vessels and some distance in front. When filled with slag the cars may be pulled out to the rear through the repair shop. These cars are not yet in use, as the acid slag, though generally pretty liquid, is not in sufficient quantity to be a nuisance, and mostly goes in the ladle. Handling of ingots and moulds is much facilitated by the arrangement of pit, cranes, and tracks shown, and the important point of transportation of both waste and finished product seems pretty well provided for.

The possible need of cupolas for remelting the Sunday-iron and using up scrap was recognized in the design, but no cupolas were put up. It would seem that, for a plant designed to work mixed cupola and direct-metal, and having large furnace capacity, the cupolas might advantageously be placed near the furnaces, and be considered, in fact, adjuncts to them; but so much depends upon local conditions that a different arrangement might be the best. If

the chief reliance is to be upon cupola-metal, the cupola-house should, of course, adjoin the converting-house, but if the office of the cupola is merely to remelt Sunday-iron and eke out deficient furnace-capacity, cupolas near the furnaces seem to be the proper arrangement. One possible good result seems likely to follow the location of the cupola at the furnace—the furnace-manager will investigate its various zones, determine whether it has any of Bell's alphabetical tendencies, and write a paper about it.

It is, I think, not altogether a fancy of mine that this plant works more smoothly and with less friction than any with which I am acquainted. The perfect regularity and ease with which all the operations are conducted—due to the special adaptation of means to ends—strikes the observer at once, and to one familiar with Bessemer work it is at once fascinating and satisfactory.

The South Chicago practice differs in some points from that at other works. In the use of direct-metal it is not now singular, as one other plant is working direct with great success, but there are some details of direct practice which may be of interest; the other points are the remarkable ladle and bottom-practice and the employment of steam for controlling the temperature of the metal. It is remarkable that the use of direct metal has been so long postponed in this country. The first Bessemer (or, rather, Kelley) blow at Wyandotte, in 1864, so well described by Captain Hunt in his *History of the Bessemer Manufacture in America*,* was made with metal direct from the furnace, and the practice, though interrupted by experiments with reverberatory furnace and cupola, continued to be direct-metal work until the plant was abandoned. The singular silence of everybody connected with the plant at Wyandotte (broken only by Captain Hunt's paper above referred to) as to the working results there, leaves a blank which imagination can, perhaps, fill; and the most definite information I have been able to get is to the effect that they had "a good deal of a time" with direct-metal. The Bethlehem Iron Company also experimented with direct-metal, but the results seem to have been unfavorable, and their magnificent plant, designed by Mr. Fritz with special reference to direct-working, is now using cupola-metal only.

European practice has meantime been steadily moving toward the abandonment of remelting, and very few new plants now contemplate the use of cupolas. Perhaps the superiority of our cupola-practice to that abroad will explain why we have clung to remelt-

* Transactions, v. 201.

ing, and they have been anxious to dispense with it, but I fancy that the pressure of low prices for product has had much to do with the adoption of direct-working on the other side, and will yet bring it about here. With reasonably good ores, success in working direct depends primarily upon intelligent and scientific furnace-management, and in almost equal degree upon careful and constant watchfulness in the Bessemer works. These two factors react upon each other. The information that anything is wrong with the metal is not long in travelling from the steel-works to the furnace, and the furnace-manager is compelled to keep a close watch upon his product, and take immediate steps to remedy the difficulty. With cupola-working, the always magnanimous Bessemer-man will attribute the trouble to some defect in his own work, and the furnaceman will maintain that calm serenity of mind, which characterizes him under ordinary circumstances, and which it is the chief mission of direct-working to dispel.

But with the best of furnace-work some means of knowing what sort of metal is about to be blown must, of course, be at the disposal of the Bessemer works; and at South Chicago the plan was adopted of taking a test from the metal as it ran to the vessel, which was cast in a chill and cooled at once in water. The fracture of this "chill" enables the blower to judge very accurately of the probable heat of the charge, and the necessary additions to be made. After a little practice mistakes were rarely made, and the "chill" has the advantage over a silicon-determination that it registers, so to speak, the effect of other elements besides silicon, and gives the operator a tangible record of the metal he is dealing with. The quick determination of silicon has been brought to great perfection at the Edgar Thomson Works, and is an excellent guide to practice; but it seems to me that the chill furnishes all the necessary information in a better form, and while knowledge of the silicon-percentage is of great importance to the furnacemen, yet the Bessemer works is better served with a test-sample. It is surprising what great variety of metal the Bessemer process can deal with under favorable circumstances. White iron with $\frac{3}{4}$ of 1 per cent. of silicon has been successfully converted, and so has iron with 4 per cent., with all the intermediate grades, but the best metal for direct-working is found to be that with from 1 to $1\frac{1}{2}$ per cent. silicon, pretty gray, and with not more than 1 per cent. manganese. Ten tons of such metal can be blown in ten to twelve minutes, and, phosphorus being low, will make good steel. The higher limit of silicon is perhaps the safest, as

affording reasonable security against sulphur, and there is no difficulty in dealing with $2\frac{1}{2}$ or even 3 per cent. of silicon—quantities which insure that sulphur in hurtful amount will not be present.

It became evident very soon after work began at South Chicago that there would be difficulty in keeping down the heat of the metal by means of scrap alone, and I therefore put in steam-connections to each of the vessel blast-pipes, with the object of cooling the metal by means of steam, but had no opportunity to get the apparatus into working shape. To Mr. W. R. Walker is due the credit of having made the use of steam in the Bessemer process a success on a large scale, for all previous applications had been hardly more than experimental. Though the cooling effect upon molten iron of steam used by itself had been known before the time of Bessemer's early experiment, yet I believe there is no record of the successful use of steam with air for the express purpose of cooling the bath in the Bessemer vessel earlier than the experiments of Captain Jones, of the Edgar Thomson Works. As used at South Chicago, the apparatus (if it can be called so) consists of a 2-inch pipe tapped into the blast-pipe leading to each vessel where it leaves the regulating valve, with drip-cocks for drawing off water of condensation, and a steam-gauge, with the necessary globe-valves for regulation. As soon as the metal in blowing shows signs of undue heat, steam is turned on (care being taken to drain any water from the steam-pipes) and kept on until, in the judgment of the blower, the proper cooling effect is produced. An enormous quantity of steam is sometimes required, the full opening of a 2-inch pipe at 50 pounds pressure being occasionally given. Nothing can be neater or more effectual than this way of cooling metal; there is no handling of scrap, and the whole matter is under the complete control of the blower, who, by opening a valve, can regulate the temperature of the metal with the greatest nicety. A capital advantage of steam is that with its aid metal high in silicon can be converted without difficulty, so that a furnace may make such pig, in which sulphur may be kept low, without complaint from the Bessemer works. It may be of interest to note that no removal of sulphur or phosphorus is effected by the use of steam. The mode of action of steam in cooling the metal is, perhaps, open to question, but it is probable that the steam, on reaching the tuyere-box, has wholly condensed into watery vapor which is raised to steam in passing through the bath, thus absorbing a large amount of heat. There may be a further absorption by decomposition of water, but that this will have much influence seems

unlikely from the short time available for the reactions, and from the fact that sulphur is not appreciably removed. That the steam is condensed before reaching the metal is evident from the fact that the tuyere-box and blast-pipe are quite cold, whereas without steam these parts are usually hot enough to burn the hand, and, indeed, water runs freely from any leaky joint about the bottom. That there is any danger of explosion with reasonable care is amply disproved by the experience at South Chicago, though it must be confessed it has rather a risky look to see a heat blowing in a vessel and water running in streams out of the tuyere-box. No danger is to be apprehended, however, so long as the blast of air is simply drenched with watery vapor; it is the intrusion of liquid water beneath the metal that is to be feared, and this can be effectually prevented by putting a drip on the lower side of the tuyere-box, so that any water accumulated there may be drained off between blows. Washing of the clay packing around the butts of the tuyeres is prevented by mixing some hydraulic cement with the clay, which then sets and perfectly resists the action of the steam. For any Bessemer works liable to occasional hot heats the use of steam is important; for a direct-metal plant it may almost be said to be indispensable. By using steam the consumption of scrap may be confined to what the Bessemer works itself produces, and the unmerchantable scrap from the blooming and rail-mills, leaving the rail-ends to be sold or rolled into wire-rods, etc., for which there is always a market. The saving of the time and labor employed in getting scrap to the vessels and handling it there is a not inconsiderable item, and, on the whole, I do not know any point of practice which better commends itself for convenience and economy than the use of steam.

The refractory material practice in the West generally is very good. Vessel linings are "balled up" with finely ground patching-stuff and last for months, and bottoms are made in much the same way. At South Chicago a 10-ton vessel has been lined up in this way in seven hours, and some remarkable results have been got with bottoms. A bottom has made as many as twenty-nine heats, yielding 238 tons of ingots; and the average life of bottoms for a whole month has been eighteen and one-half heats, yielding 159 tons of ingots. In a paper read before the Institute at the Cleveland meeting, in 1875,* I stated, with some pride, that the average

* Transactions, iv. 132.

life of bottoms at North Chicago had reached the unheard-of figure of eleven heats of 5 tons each. The two figures, 55 and 159, represent pretty accurately the state of Bessemer practice at the different dates, and the South Chicago figure, being got with direct-metal, is particularly creditable to the management.

The product of ingots at South Chicago has not been large, for the reason that the blast-furnace capacity has been limited, but I have every reason to believe that with plenty of metal the plant will give a good account of itself. As a rule, the product of the furnaces was not sufficient to keep the plant going, but when metal was to be had some very fair runs were made. The best twelve hours' work yielded 381 tons of ingots in forty-five blows, and there appears to be no reason why this rate of working may not be maintained or even exceeded. One hindrance to large output, which was foreseen, and so far as possible provided for, is the large number of small ingots cast. Thus, to get 381 tons, no less than 436 ingots had to be handled, with an equal number of moulds. The cranes and tracks are, however, so arranged that this large amount of handling is done without difficulty and without interfering with any other operations. But some mechanical device is very much needed for handling ingots and moulds; the work about the pit is now the most severe, and in the aggregate most expensive, labor about a Bessemer works, and it would seem that there is room for some device which shall save both time and labor.

It is to be hoped that a thorough trial of the basic process may be made in this plant, in order to test the fitness of the arrangements made with that end in view. If the basic process is to succeed in this country, it must be carried on in works designed with some reference to the process and provided with the necessary facilities. South Chicago being the only works in the country which has been built with any such idea, the result of such a trial will be looked for with much interest.

It need hardly be said that in the design of this plant I had the benefit of Mr. Holley's counsel and experience, and I wish to record here my deep sense of obligation to him, which his untimely death prevented me from formally expressing during his lifetime. No one was more anxious than he for the success of the new plant, and my only regret, on the day when, after months of preparation, steel was at last made, was that Holley was not there.

I have tried to make clear the objects aimed at in the design of this plant, and the means by which these objects have been accom-

plished. The conditions were somewhat novel and peculiar, and the result is a plant which, perhaps, might better have been allowed to speak for itself.

Discussion.

President Hunt: I think many of us who are in the Bessemer business will agree with Mr. Forsyth in the wish that the practicability of the basic process should be tried in Chicago. I am free to say, that here in Troy, we are not anxious for the job,

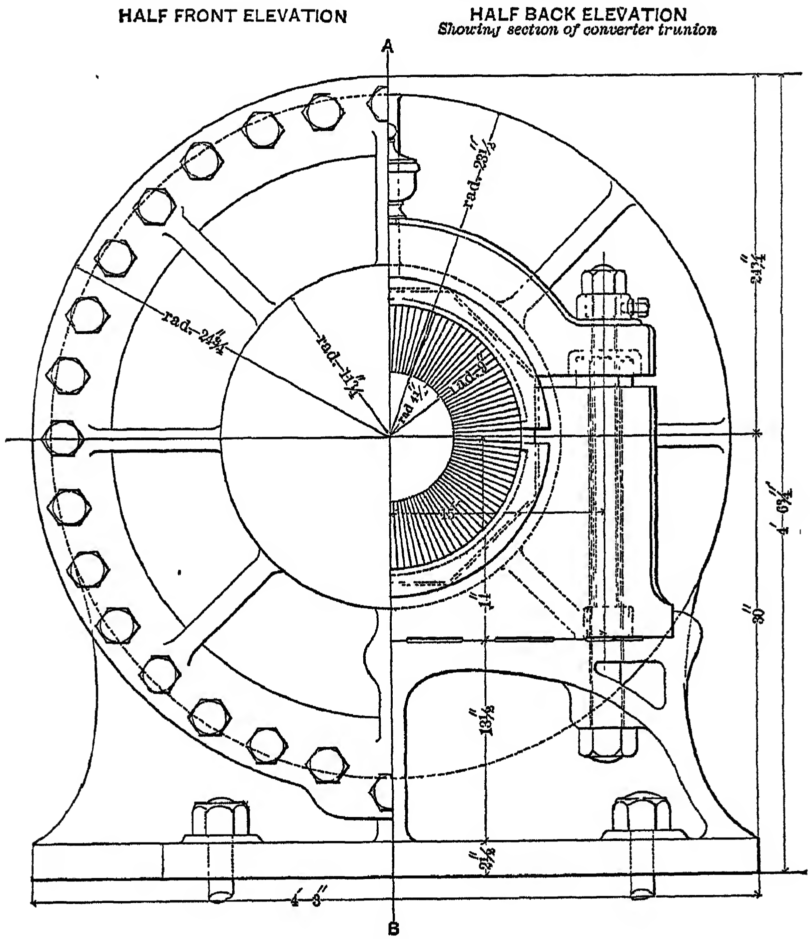

Fig. I.

and as the South Chicago plant was designed with reference to that process, it certainly is the one in the United States that can best determine whether it is a practicable thing for this country. It has

been stated by some gentlemen, who have spent time abroad investigating its possibilities in reference to its adoption in this country, that there must be a reduction of at least three dollars a ton in the price of iron for that process, before it can be done. Those peaceful gentlemen, the blast-furnace men, to whom Mr. Forsyth has referred, can tell us whether they can do this. I am told they are all being

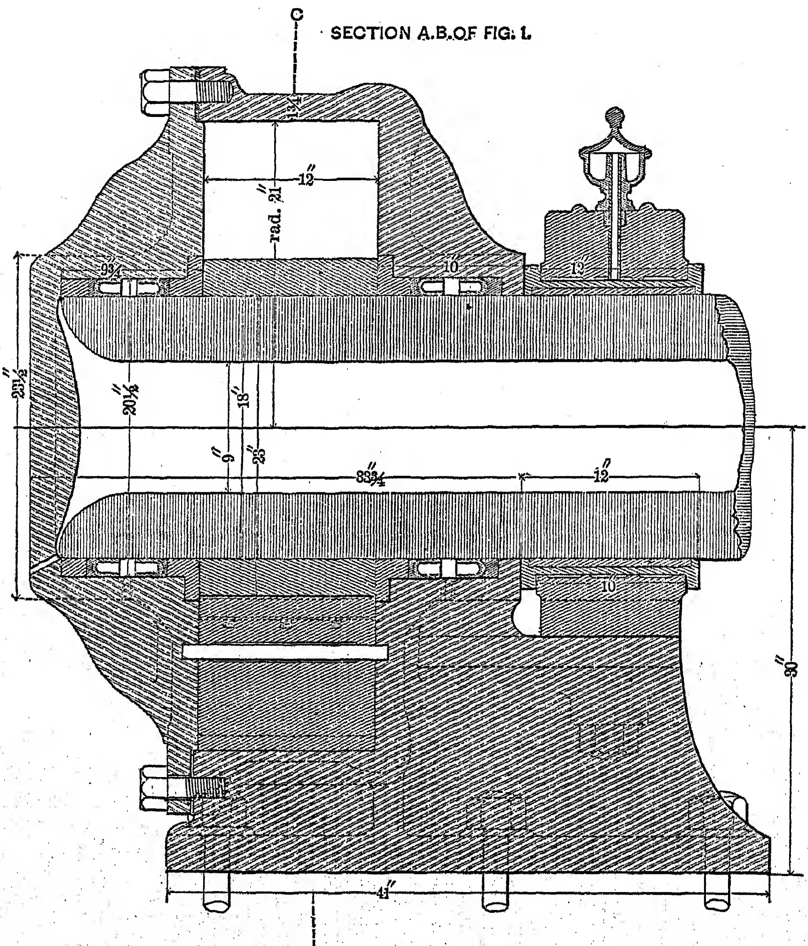

Fig. 2.

ruined at present. One of them told me that he did not know how he could afford to be in Troy, that it was only a ruined man's impulse to go in a little further that allowed him to be here at all.

But, gentlemen, I am sure you have found Mr. Forsyth's description of those works very interesting, and I hope to have it discussed by the Institute.

Mr. W. F. Durfee, Bridgeport, Conn.: I wish to call the attention of the Institute to a tabulated arrangement of some notes relative to the back-pressure in the trunnion-cylinder of Bessemer converters. The experiments, of which the table before you is the record, were undertaken some years since, at my request, in order to test the accuracy of certain calculations of my own, which indicated that the particular trunnion-cylinder which was the subject of the

SECTION C.D.OF FIG. 2.

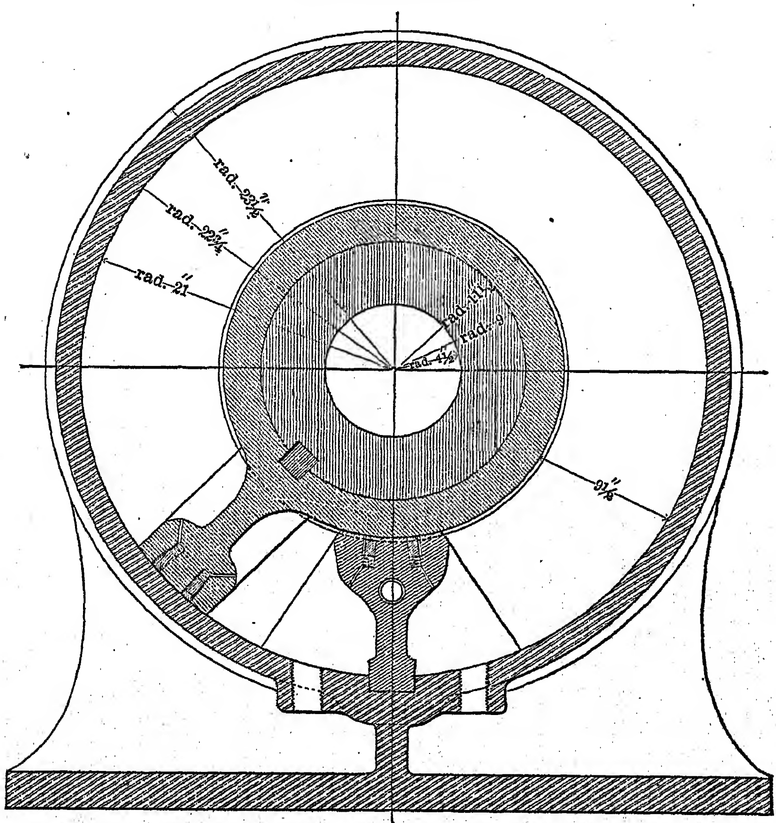

Fig. 3.

experiments was unnecessarily large, and that its use involved a considerable waste of power. I do not know that these figures have any pertinence to the plant that we have just heard described; but as bearing upon the general question of economy of power in Bessemer works, I think they will be found of interest. The pressure in the accumulator (which is the resistance to be overcome by the pumping machinery), in the works where these notes were taken, was 300 pounds per square inch.

The greatest pressure recorded in the table, 260 pounds per square inch, is when the vessel is going down after blowing; but opposed to this is a back pressure of 60 pounds, which, if absent, would have permitted a pressure of 200 pounds per square inch to do the work, thus showing a loss of at least 30 per cent. of the power stored in the accumulator. A similar comparison of some of the other pairs of pressures recorded, will show a much greater loss.

Some years since I designed a mechanism for turning converters, as a substitute for the rack motion in common use. In the accompanying drawings this mechanism is represented; it consists of a cylinder concentric with a prolongation of one of the trunnions of the converter, which passes through the two heads of the cylinder, these being provided with appropriate stuffing boxes. Keyed to the trunnion, on the inside of the cylinder, is a wing piston, which is made water-tight against the heads and circumference of the cylinder by suitable packing. Attached to the inside of the cylinder below the trunnion is a fixed abutment, which is packed water-tight against the finished surface of the hub of the wing piston. Water is admitted to the cylinder on either side of the fixed abutment, and, acting on the wing piston, turns the converter as desired.

I regard this as the simplest and cheapest method of turning converters by water under pressure yet proposed.

TABLE SHOWING PRESSURE IN TRUNNION CYLINDER OF BESSEMER CONVERTERS.

Bottom. Pounds.	Top. Pounds.	
170	155	Vessel moved up and down empty.
140	100	
210	80	
200	125	
100	120	
160	80	
220	60	
200	130	Vessel standing half way to receive metal.
200	120	Vessel going up to blow.
200	165	Vessel standing up blowing.
240	60	Vessel going down.
180	50	Vessel standing half way.
170	80	Vessel going down to ladle.
190	60	Vessel going down to empty slag.
200	80	Vessel going down to empty slag.
160	80	Vessel going up empty.

PRESIDENT HUNT: I was in hopes, gentlemen, that Mr. Durfee would refer to that time which Mr. Forsyth spoke of, at Wyandotte.

I would say to you, that I believe Mr. Durfee has the honor of having made the first blow of Bessemer steel in America. And he took the metal direct from a little charcoal furnace situated in the works of Captain Ward at Wyandotte. I went there some months, perhaps a year, after the first steel was made. They were still having some trouble, and Mr. Durfee, referring to the primitive way of turning down the converter, said: "We generally turn it down by man-power." I know sometimes it went down and sometimes it did not. If it did not go down we had trouble. And when we got the stuff out of it, we did not know what it was. But, nevertheless, Mr. Durfee got some good steel from the metal directly from the blast furnace, and made the first Bessemer steel in America, and the first steel that was rolled into rails in this country. As there has been a newspaper controversy on this subject, I may as well say, that I know that Mr. Durfee made the steel that was rolled into rails in the Chicago Rolling Mill in 1865. The great trouble with us in our early Wyandotte practice was, that we did not have silicon enough in the metal to keep the heat up, or blast enough from the blowing-engine. Sometimes we succeeded in getting one ingot out and sometimes two, the rest of the charge chilling in the converter. But the process went on to success, and many of us have lived to see it.

Mr. Durfee: I did not refer to that particular matter, while speaking, because to-morrow I propose to read a paper descriptive of the chemical department of that experimental works, when I shall have something to say relative to the point that you have spoken of; but just now I desire to say a few words explanatory of what Mr. Forsyth has called the singular silence of all those connected with the early work at Wyandotte. So far, sir, as I am answerable for that silence, I will say that it has been occasioned by no fear of publicity, but from a feeling that no one cared to know anything of that early work. But recently I have had so many inquiries about it, that I have been induced to write the paper which I shall read to-morrow; and at an early day, either before this Society, or some other, I intend to read another paper descriptive of just what was done, and my reasons for doing it, in the mechanical department of the works at Wyandotte.

The difficulty with the blast at Wyandotte, to which you have referred, is very easily appreciated now; but, when the blowing engine for that apparatus was designed, the English works were all blowing their steel with 8 pounds pressure of blast, relative to which

my reasoning was this: that if we were going to do work in a hurry, if we wished to get air through the metal before a large part of it was destroyed by oxidation, we must have much more pressure than that. My design was for an engine to blow 14 to 16 pounds pressure, but as soon as I had got my ideas up to 16 pounds, the English had got theirs up to 25 pounds, and my blowing engine was old-fashioned before it had got fairly into use.

MR. FORSYTH: Mr. Durfee's remarks about the pressure in hydraulic cylinders I think are very interesting. I have made some investigations of that sort myself, and I found not quite as great differences in the pressures as he records, but still great. Using an indicator, and taking diagrams from which the mean pressures were afterwards deduced, I found about 90 pounds back-pressure, with something like 240 pounds on the other side of the piston, which corresponds quite closely with some of Mr. Durfee's results. I think investigations of that sort are very profitable, and more of them ought to be made. We should feel very much obliged to Mr. Durfee for calling attention to it.

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*RŒSSLER'S METHOD OF MANUFACTURING SULPHURIC ACID AND SULPHATE OF COPPER.**

BY ARTHUR F. WENDT, NEW YORK.

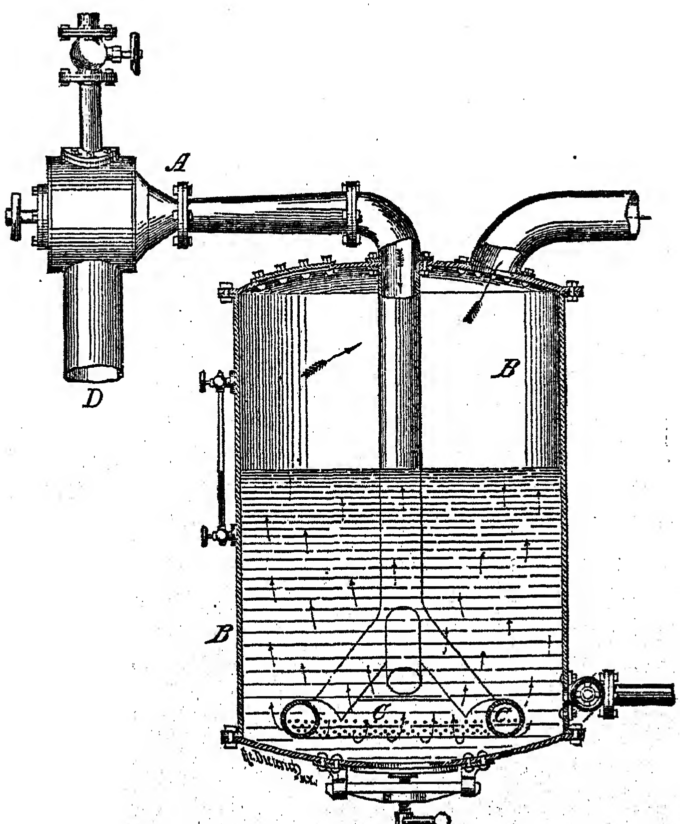
THE following experiments and researches were originally conducted by Dr. Heinrich Rœssler, chief of the German Gold and Silver Parting Establishment at Frankfort-on-the-Main, for the sole purpose of abating the nuisance created by the discharge into the air of the sulphurous and sulphuric acids generated in the process of parting bullion by sulphuric acid.

The results achieved have, however, an important bearing not only on this process, but are of value in the manufacture of sulphuric acid and sulphate of copper from sulphurous gases derived from any source. It has now been in successful operation for a term of years at Dr. Rœssler's own works, and has been lately introduced with satisfactory results at the royal mints of Kremnitz and Munich, and the well-known establishment of Johnson Mathey & Co., of London.

* Patented in England, France, Italy, Germany, Hungary, and the United States. The author represents the inventor in this country.

The process, briefly described, is the introduction of sulphurous gases, mixed with air and steam in a finely-divided state, into a solution of blue vitriol. This salt acts as the carrier of the oxygen of the air, continuously converting sulphurous into sulphuric acid. It replaces the nitric acid of the lead chambers.

Laboratory experiments readily show the reactions occurring. If sulphurous acid is allowed to pass through a hot and not too acid solution of blue vitriol in such manner as to keep the liquid in



violent ebullition, it will rapidly change the bright blue color of the solution to a dirty green. An addition of water to the green liquid will precipitate metallic copper. Salt will precipitate subchloride of copper. These reactions are proofs of the reduction of a portion of the sulphate of copper by the sulphurous acid into a sulphate of the suboxide, which remains dissolved in the hot solution of blue vitriol To the presence of the suboxide is due the change in color.

If, now, air is blown into the dirty green solution, the bright blue

color is gradually restored, owing to the re-oxidation of the green sulphate of the suboxide into blue sulphate of the protoxide, the blue vitriol of commerce. The reactions of reduction and oxidation go on indefinitely and practically simultaneously in the apparatus devised by Dr. Rœssler.

A sketch of the apparatus is here shown. A leaden tank (B), some eight or nine feet high and five feet diameter, carries a six-inch lead pipe (A), branching at the bottom and supporting a ring (C), with numerous small holes drilled on the lower side. A Korting steam injector draws the gases containing the sulphurous acid from the flue (D), and forces them through the blue vitriol, which partly fills the tank or converter.

From 80 to 90 per cent. of the sulphurous acid is converted into sulphuric acid, and any free sulphuric acid that may be present in the gases forced through the converter is completely absorbed by being brought into intimate contact with water. The acid generated in the converter reaches a strength of 15° to 20° B.

By preference, the converter is now employed in Europe to manufacture blue vitriol. Sulphurous acid gas generated in metallurgical or other commercial operations invariably contains a small percentage of sulphuric acid, formed either by oxidation of sulphurous acid by the oxygen of the air, or carried along mechanically, as is the case with gases derived from parting bullion. It is only necessary to fill the converter with water, introduce copper, as "cement" or otherwise, into the apparatus, and turn on the injector, and the reaction begins. At first only the sulphuric gases are absorbed, and dilute acid results, which at once dissolves copper and makes blue vitriol, and then this salt acts on the sulphurous acid, as above described. Thus it becomes possible to produce a solution of blue vitriol, which gradually becomes concentrated to 35° B. in the converter. When this stage of concentration has been reached, the solution can be drawn off and replaced by a fresh charge of water. The blue vitriol may be crystallized and sold as such, or the metallic copper may be recovered by a dynamo machine, or precipitated by other means.

The importance of Dr. Rœssler's process for parting establishments, government mints, and other chemical and metallurgical works and factories located in large cities, cannot be over-estimated. By the use of the converter, at a very small first cost and trifling expenditure for space, the means are provided of profitably utilizing gases which have hitherto been discharged into the air, to the damage of the public health and surrounding vegetation.

Many copper mines and other sulphuret mines, distant from railroads, will find in this process a ready means of obtaining a supply of sulphuric acid without erecting and operating expensive lead chambers.

In parting works a marked advantage of the process is the entire freedom from acid fumes of the rooms in which the parting kettles are used, and the consequent good health of the operators.

In connection with this description of Dr. Rœssler's process, it may be of interest to give an account of the many unsuccessful experiments made to abate the evil of escaping acid fumes. To obtain reliable data in the experiments, the gases operated on were analyzed by measuring the volume required to decolorize a standard potassium permanganate solution, and then determining the SO_3 in this solution by precipitation with BaCl. Computation will readily determine the amount of SO_3 due to the SO_2, and the difference will give the SO_3 present as such. In this manner the average of one cubic meter of gas from parting-kettles was found to contain 100 grams SO_2 and 20 grams SO_3, or 4 per cent., by volume, of sulphurous acid gas.

I would here call attention to the fact that to make the manufacture of acid in lead chambers a commercial success, at least 8 per cent. of sulphurous acid should be present in the gases. It is one of the advantages of Dr. Rœssler's process that even a fraction of 1 per cent. of sulphurous acid can be utilized at a profit.

But to return to the various experiments. Freytag's system of absorbing gases containing less than 1 per cent. by volume of SO_2 and 2 to 3 grams SO_3 in 1 cubic meter, was as follows: The gases were allowed to ascend a tower, in which they encountered a heavy spray of 50° sulphuric acid. The SO_3 was absorbed pretty effectually, but the SO_2 remained in great part unabsorbed.

At Schoppinitz, in Silesia, roasting furnace-gas containing only $\frac{1}{4}$ per cent. by volume of acid was exposed to showers of milk of lime. The absorption was quite complete, only 10 per cent. of the acid escaping, but the system was cumbersome, and was finally abandoned.

Clemens Winkler has used the following systems in ultramarine works; gases from such works contain $\frac{1}{2}$ to 2 per cent. SO_2.

Lead-towers with showers of 60° SO_3, containing some NO_5.

The same with showers of sulphide of sodium.

Towers filled with limestone or wrought scrap-iron, combined with showers of water.

The last two systems were quite successful in absorbing the acid,

but were a constant source of expense, and produced sulphate of lime or iron of no commercial value, and almost as difficult to get rid of as the noxious gases.

Turning now to Dr. Rœssler's experiments. He recognized, almost at the beginning, the fact that the sulphuric fumes create the main annoyance. Sulphurous gases are considerably lighter, and are, to a large extent, diffused by the air before they fall to the ground and create annoyance.

His first experiments were made entirely with this fact in view, and consisted in passing the gases through a layer of incandescent coke. The sulphuric acid was, it is true, reduced to sulphurous acid, but in ascending the chimney of the works a portion, at least, was reconverted, and eventually the annoyance of stoppage of the draught led to the final abandonment of the system.

Dr. Rœssler next turned his attention to absorption of the gases by water. A large tower, 65 feet high and 9 feet square, was filled with coke, and a plentiful shower of water passed over it. A long conduit, connecting the tower with the parting-kettles, was also filled with numerous jets of water. However, notwithstanding the fact that the temperature of the gases was reduced by two-thirds, and a large outlay for water incurred, the system absorbed only one-half of the sulphuric acid and less than one-quarter of the sulphurous. This system, by the way (although in a cruder and less complete form), is that used by the United States assay offices in New York and San Francisco. How incomplete is its operation, everybody living within several blocks of these works can bear testimony.

Subsequent experiments led to the abandoning of the coke filling of the lead-tower and its replacement by an extremely fine spray of water, created by jets of water under heavy pressure impinging on platinum plates. The success of this system was somewhat greater. Three-quarters of the sulphuric acid was absorbed, but only one-quarter of the sulphurous could be caught.

Finally, and quite accidentally, Dr. Rœssler's present system, as described, was hit upon. It has been eminently successful, and where used has completely stopped the only too well-founded complaints of discharging the noxious gases into the air, and has converted a source of annoyance and expense into a source of profit.

AN EXPERIMENTAL WORKING OF SILVER ORES BY THE LEACHING PROCESS.

BY J. H. CLEMES, SONORA, MEXICO.

THE process of leaching silver ores with sodium hyposulphite is comparatively new, and published accounts of the details and losses of the process are as yet very few. The following account of a careful series of experiments to determine the actual loss in this process may therefore be acceptable to members of the Institute.

The ore treated was highly calcareous, and the principal sulphide present was iron pyrites. Following is an analysis by Professor Price, of San Francisco, of the ore treated:

	Per cent.
Silica,	15.13
Sulphur,	13.31
Arsenic,	9.82
Iron,	17.33
Alumina,	1.35
Zinc,	4 92
Lead,	1.78
Carbonate of lime,	33.78
Magnesia,	2.58
	100.00

Ten tons were crushed dry with a 30 × 30 screen = 900 holes per square inch. In order to feel our way with this ore, two experimental or "pilot" charges were roasted.

PILOT CHARGE NO. 1.

Treated 1000 pounds in a four-hearth reverberatory.

8.30 P.M.—Entered fourth hearth, remaining there one and one-half hours; sulphur began to burn.

10 P.M.—Changed to third hearth; ore became red-hot half an hour after entering; the fireplace was kept almost destitute of fuel.

2.30 A.M.—Changed to second hearth. Charge continued, giving off a large quantity of sulphurous fume; the fireplace was kept dark.

3.30 A.M.—The combustion of sulphur much decreased; the ore swelled a little.

4 A.M.—The mass began to lose its glow and to become dark.

Fuel was thrown on the grate-bars until the arch of furnace was red.

4.30 A.M.—Combustion of sulphur ceased; 60 pounds of salt = 6 per cent. were added. The salt was dry and finely sifted.

5 A.M.—Charge passed to first hearth, a small evolution of sulphurous acid still continuing. Although the fire was moderately urged, the chlorine fumes were not nearly as copious as could be wished.

5.30 A.M.—The amount of chlorine fume was very much decreased; the furnace was kept at a good red (*coup de feu*).

6 A.M.—The charge was considered rendered, and was drawn.

It evolved hardly any chlorine, even under a sharp fire—a marked difference from the siliceous ores that we generally treat here; the latter continue to give off chlorine fumes after being drawn, the cause being the action of the silica on the common salt, which is always present in excess.

The roasted ore assayed 245 milles = 71.5 Troy ounces per ton (2000 pounds) avoirdupois.* By crucible assay, as often happens with ores in which the silver exists as chloride, the result by the scorification method is less; in this case the assay by the latter method was 218 milles.

Three portions of 300 grains each were treated with boiling concentrated sodium hyposulphite, and their residues assayed in the usual way; the buttons weighed .152 and .150 grains = 79 per cent. and 80 per cent. chloridized.

The pile was moistened and allowed to stand two days. 300 grains, treated as before, left a button weighing .138 grains = 81 per cent. chloridized.

Pilot Charge No. 1 b.

This was composed of:

900	pounds Pilot charge No. 1.
200	pounds raw ore.
1100	pounds.

* As 1 mille is taken = 0.001 per cent., the above assay is, therefore, 0.245 per cent., or, as is often written, 245 grams per 100 kilograms.

It was roasted in a five-hearth furnace.

3 P.M.—Entered fifth hearth.

4 P.M.—Changed to fourth hearth.

6 P.M.—Changed to third hearth.

7 P.M.—Entered second hearth.

Half an hour afterwards a very slight combustion of sulphur began.

8 P.M.—The mass received 4 per cent. of salt, and began to swell considerably.

8.30 P.M.—Changed to first hearth.

9 P.M.—The charge worked well, giving off a great deal of gas, swelling, and becoming spongy. A light fire was used.

10 P.M.—Strong evidence of active chlorination.

11 P.M.—The charge appeared to be rendered, and was withdrawn.

300 grains of the roasted pulp were digested with sodium hyposulphite; the residue yielded a button weighing 0.016 grains.

Repeated, 300 grains gave a button weighing 0.015 grains.

The roasted pulp was weighed after sprinkling:

First weight, 1752 pounds; second weight, 1730 pounds; deducting 9.88 per cent. moisture = 1569 pounds net.

In its double passage through our furnace it picked up other ores and dust from corners, etc.

200 pounds of this roasted pulp were placed in a small vat and treated with cold spring water for the purpose of dissolving out the soluble salts of base metals present in the pulp. A part of the liquid escaping from the bottom of the vat was caught in a bucket and the metallic salts held in solution were precipitated as sulphides by the addition of a little calcium sulphide.

The precipitate was dried, and yielded by assay 3.696 per cent. silver; the operation was repeated half an hour afterwards, yielding a precipitate which contained 0.452 per cent. silver.*

Our usual working solution of hyposulphite was then turned on the pulp and allowed to run three days; specific gravity of solution, 2° B.

The tailings obtained assayed 7 milles = 2.04 ounces per ton of

* It will be observed that a large loss of silver occurred in washing out the base metals, due to the solubility of silver chloride in brine. This loss will not be tolerated in treating eight and one-half ton lots, as the first wash will be suppressed. On the large scale, also, this loss can be avoided; further on we will describe the modes of effecting this.

2000 pounds. The chlorination was further advanced by allowing the moistened pulp to lie heaped before leaching. It is still more advantageous, in addition to the above precaution, to allow the roasted ores to lie red hot as long as possible.

Pilot Charge No. 2.

Roasted in a five-hearth furnace.

1 P.M.—Entered fifth hearth; sulphur began to burn half an hour afterwards.

2 P.M.—Changed to fourth hearth; the hot pulp ran over the whole hearth like quick-silver.

3.30 P.M.—Changed to third hearth. The sulphur burned strongly, the arch becoming completely red. Very little wood was kept in the fireplace.

5 P.M.—Changed to second hearth. The charge did not swell; it ran before the rake, and great care had to be used to prevent its running out at the working-door.

6 P.M.—Added 8 per cent. salt, well dried and finely sifted. The charge immediately began to swell and to give off copious torrents of gases.

8.30 P.M.—Entered first hearth, the charge still containing some sulphur. Hardly any wood was kept on the fire-bars. Still larger volumes of gases were evolved; the charge was much increased in bulk.

A sample was taken from the furnace, and a chlorine assay made in the usual way showed 76.2 chloridized, the two 300 grain samples giving buttons both weighing 0.118 grains.

The pulp itself only assayed 164 milles, having, in its passage through our fire-ovens, taken up a large amount of poor ore from corners, etc. Our furnaces were well scraped before introducing this ore, and a charge of tailings was put through ahead of it to clean off the floors and corners.

11.30 P.M.—A fresh sample taken; buttons from 300 grains weighed .026 and .024 grains = 96 per cent. chloridized.

12.30 A.M.—Charge still contained a very little sulphur.

1.30 A.M.—Charge commenced to grow dark; the gas evolved smelt strongly of chlorine; no smell of sulphurous acid could be perceived.

2 A.M.—The charge was considered to be roasted dead, and was withdrawn.

The above chlorine assay proves that it might have been withdrawn *two and one-half hours* before it was.

The heap, after cooling naturally, was sprinkled, and 2 samples of 300 grains were taken twenty-four hours afterward, and gave .028 and .038 grains = 94.5 per cent. chloridized.*

The roasted pulp was weighed: first weight, 1704 pounds; second weight 1700 pounds; deducting 7.52 per cent. moisture = about 1570 pounds net.

The raw pulp having originally weighed 1000 pounds, it took up from tailings, etc., from bottoms and corners, during its passage in five hearths 9′ × 9′ each, 570 pounds.

This, of course, vitiates the result very considerably, but we were very loath to pass through the large parcel without having some insight into the working of the ore. Nothing analogous happened on working the large lot, because the first charge or two were the only ones affected.

A further chlorine assay of the roasted pulp was made, buttons from 300-grain samples, digested with hyposulphite, giving 0.028 grains and 0.030 grains = 94 per cent. chlorinized.

Experiments were made with a view to ascertain the loss occasioned by washing the roasted pulp with spring water. 100 grains were washed by decantation and filtration; the residue yielded by assay a button weighing 0.033 grains, the ore before washing containing 0.164 per cent.

Nothing analogous to this occurs on the large scale, because the brine is so rapidly diluted by the influx of large quantities of water. One quintal of roasted pulp from Pilot No. 2 was washed several hours in a small vat; assays of the ore after this wash gave 169 milles and 170 milles—the original unwashed ore assaying, as before, 164 milles. There was, as before, some loss of silver in this operation, but the water removed the excess of common salt and certain soluble metallic salts,—probably, in this case, mostly sulphate of iron,—so that the washed residue was richer in silver than the original, its weight being less.

Two more samples from this roasted pulp were assayed, giving 166 and 158 milles.

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* With this charge, as with its predecessors, no pains were taken to obtain it from all parts of the pile of raw pulp, as we were not then aware of the great differences of grade existing between the different classes stamped. The roasted pulp assayed by the crucible, 0.164 per cent. and 0.163 per cent.; by scorification, 0.138 per cent.

THE MAIN LOT.

Weights of Raw Pulp.

16,639 pounds was the weight of the main lot roasted.
100 pounds were sent to San Francisco.
1,000 pounds were taken by Pilot Charge No. 1.
200 pounds were added to roasted pulp of Pilot Charge No. 1, forming Pilot No. 1 b.
1,000 pounds were taken for Pilot Charge No. 2.
50 pounds taken for samples.
221 pounds of small rock, gravel, etc., which remained in the mortar-bed after finishing the stamping.

19,210 pounds.
720 pounds difference in weight.

We use a wet mill, and in stamping dry, cannot prevent "dust loss."

Part of the loss is moisture expelled from the sheet-iron plates, and part was due to the fact that the ore was partially burnt on the plates.

20,000 pounds weight of ore.

Free sulphur was condensed on the upper strata of the ores lying on the sheet-iron plates.

The pulp (main lot) was twice weighed, once on entering room from stamps—16,656 pounds; once on leaving room for furnaces—16,622 pounds;—average, 16,639.

Assays.

Samples were taken after removing the two pilot lots and the sample for San Francisco:

364 milles	= 106.2	ounces	per ton	of 2000 pounds.
370	" 107.7	"	"	"
375	" 109.4	"	"	"
378	" 110.2	"	"	"
377	" 110	"	"	"
374	" 109.1	"	"	"
376	" 109.7	"	"	"
376	" 109.7	"	"	"
380	" 110.8	"	"	"
381	" 111.1	"	"	"

Average, 375.1 milles (0.375 per cent.) = 109.4 ounces per ton.

The silver contained is 16,640 pounds @ 0.375 per cent. = 62.400 pounds avoirdupois.

Roasting of Main Lot.

Before charging any of this lot four charges of tailings were sent ahead to clean off hearths, corners, etc.; since these tailings did not assay more than 0.005 per cent., any small residue of them remaining in the furnace may be regarded as neutral. The passage of these inert tailings left the furnaces cold, and the first ore-charges worked very slowly.

The ore was roasted in a six-hearth reverberatory furnace, each hearth being 9 feet square. Each charge weighed 1000 pounds. With a more intimate knowledge of the ore, very much larger charges can be used.

The salt used was eight per cent. of the weight of the ore, *i.e.*, 80 pounds to each charge.

6 P.M.—Entered sixth hearth.

7 P.M.—Changed to fifth hearth, a new charge entering the sixth.

8.30 P.M.—Changed to fourth, there being no signs of combustion of sulphur, although the second hearth was completely red.

9 P.M.—Second charge changed to fifth hearth.

9.15 P.M.—Third charge entered sixth hearth. Sulphur began to burn in first charge in fourth hearth.

10 P.M.—Changed first charge to third hearth; the hearth became red-hot through the energy of combustion of charge.

10.15 P.M.—Changed second charge to fourth hearth; its sulphur began to burn.

10.45 P.M.—Changed third charge to fifth hearth.

11 P.M.—Fourth charge entered sixth hearth.

11.30 P.M.—First charge entered second hearth.

11.45 P.M.—Second charge entered third hearth; it was red-hot.

12.30 A.M.—Added the salt to first charge.

1.30 A.M.—Changed it to first hearth; it still emitted sulphurous fumes.

2.30 A.M.—Added salt to second charge *while yet in the third hearth.* This was done to begin the chlorination in that hearth, so that less should remain to be done in the other two.

3 A.M.—Sulphur began to burn in the *fifth hearth.* There were signs of very active chloridizing in the first hearth.

5.30 A.M.—First charge was considered done, and withdrawn.

Sulphur began to burn in the sixth hearth: it will be observed that a cold furnace fifty-four feet long was very rapidly warmed up. This ore can be chlorine-roasted with a very small expenditure of fuel.

8 A.M.—Second charge was drawn. Another charge received its salt in the third hearth.

9 A.M.—The second, third, fourth, and fifth hearths were completely red-hot, although very little wood was kept on the fire-bars; the fire-place measures only 4′ 6″ × 1′ 10″, the bridge being 1′ 1″ high.

The charge in the fire-hearth always appears dark in color, only glowing when moved with the rake. It speedily assumes the appearance of well-roasted ore, even when samples removed from it give off a strong odor of sulphurous acid; *i.e.*, when it is known to contain intermixed raw sulphides.

11 A.M.—Charge No. 3 was drawn. After this the following charges continued to be drawn at intervals of from two to three hours; *salt was invariably added in the third hearth.*

In the night we saw plainly that the three hearths furthest from the fireplace were much hotter than the three nearest to it. This indicates the advantage of a continuous progressive furnace for this ore.

We can see no reason why this ore should not be roasted fast by people accustomed to it; the furnace might be as long as eighty feet. If a mechanical furnace be used the ore could be advanced to the red-hot stage by the waste heat from it.

As soon as our own ores entered the furnace, after the last charge of these was done, the furnace rapidly began to cool.

Assays of Roasted Pulp.

	323	milles =	94.2	troy ounces	per ton	of 2000 pounds.
	315	"	91.9	"	"	"
	313	"	91.3	"	"	"
	316	"	92.2	"	"	"
	313	"	91.3	"	"	"
	313	"	91.3	"	"	"
	321	"	93.6	"	"	"
	312	"	91	"	"	"
	311	"	90.7	"	"	"
	312	"	91	"	"	"
Average,	314.9	"	91.8	"	"	"

The ore was twice weighed:

First weight,	17,474	pounds.
Second weight,	17,564	"
Mean,	17,519	"

As was done with the raw pulp, a small portion was taken with a U tool from each hand-barrow on weighing; half the samples are from the first weighing, half from the second.

Furnace Loss.

We have:

55.167 pounds fine silver in the roasted pulp, being 17,519 pounds of pulp, assaying 0 3149 per cent.
62.400 pounds fine silver was contained in the raw pulp.

7.233 pounds fine silver = 11.6 per cent. is the apparent loss.

During the roasting of these ores the draught was kept very sluggish, and the pulp was purposely not raked in the sixth hearth. On dropping the ore into that hearth and on shovelling and raking it in the other hearths, considerable dust was evolved, which passed into our main flues.

Our flues are 7′ high by 5′ wide, and are only cleaned out once a year. They can only be cleaned out after the furnaces have been shut down several days. It was, therefore, out of the question to have had them cleaned for this experiment.

We took great precautions to have the hearths very thoroughly scraped after the last charge of these ores passed through. Our own ores following the last charges of the experimental ores were tinged by the latter; part of this was from the hearths and corners, and part dust from working the ores anteceding ours.

The first two *hacienda* charges, 1500 pounds each, which followed the experimental ones, assayed 139 milles and 137 milles, the ores of the former in all the other furnaces during that day, only assaying 70 milles. This accounts for 2.040 pounds of the silver lost in roasting the experimental ores, reducing the loss to 5.193 pounds. This figure would show a roasting loss of 8.3 per centum.

The next four or five charges of *hacienda* ores were still tinged with the characteristic color of the ores of the experiment. They assayed 80 milles and 77 milles, the *hacienda* ores pure only assaying 70 milles. The ores were roasted in a furnace which had not been stopped for two years, the bottom of which is somewhat uneven.

With well-constructed dust and condensation chambers, and with what is more important still, *long and spacious flues*, the roasting-loss in these ores will be very light if the firing is done intelligently. They need very little fire.

Fifty pounds were taken from the roasted pulp while still hot; they are not included in the above weights; they would very slightly lessen the loss shown, leaving it 8 per cent.

Tests of the Roast.

Chlorine assays from the whole pile, forty-eight hours after the ores had lain moist in a vat, are as follows:

No. 1.—Buttons from 300-grain samples, boiled with concentrated sodium hyposulphite, gave .046 grains and .046 grains; original sample assayed 313 milles = 95.1 per cent. chlorinized.

No. 2 gave buttons of .052 and .046 grains; original sample assayed 323 milles = 94.9 per cent. chlorinized.

No. 3 gave buttons of .048 and .054 grains; original sample assayed 315 milles = 94.6 per cent. chlorinized.

After the first four or five charges were roasted 50 pounds were placed in a small vat and treated with our ordinary working solution, 2° B.

The tailings assayed:

18 milles = 5.25 ounces per ton of 2000 pounds.

After forty-eight hours further leaching, the tailings assayed:

15 milles = 4.38 ounces per ton.
18 " 5.25 " "

The cloth in the bottom of the vat did not filter freely.

Leaching.

The amount served to the vat was:

17,519 pounds, as before stated.
50 pounds were taken for assay-samples—25 on first weighing, 25 on second.

17,469
1,342 pounds, residue from Pilot Charge No. 2 (viz., 1462 pounds, less 7.5 per cent. moisture), were added.

18,811 pounds, total served to vat.

Silver Content.

55.010 pounds fine silver, being 17,169 pounds ore, assaying 0.3149 per cent.
2.187 pounds silver in residue of Pilot No. 2, being 1342 pounds ore, by 0.163 per cent. (mean of four assays, 166, 168, 164, 163 milles.)

57.197 pounds pure silver being total content.

Check-samples were taken from top of vat, to ascertain progress without emptying the vat:

Fifth day—	22 milles	= 6 4 ounces per ton.			
" "	22	"	6.4	"	"
Sixth "	19	"	5.5	"	"
" "	17	"	5	"	"

The roasted pulp was placed in a vat with a perforated false bottom covered with *manta* (unbleached cotton cloth). Another cloth was spread over the ore and covered with poor tailings. The latter precaution was taken to keep out ore-dust and to filter from the working solution a very small quantity of silver sulphide, which is nearly always suspended in it.

The usual bottom is a layer of broken slag with a layer of jig-tailings on top of it. The result of using the two cloths was that a stream of only say $\frac{1}{4}''$ diameter issued from the spout instead of a full stream of $1\frac{1}{4}''$; *i.e.*, the filtration was slow. Moreover, only one small precipitating tank was used, and the stream, small as it was, was often interrupted. The (filtration) leaching, instead of being completed in four days, took rather more than a week. The first leaching with spring water was suppressed.

The silver-precipitate obtained was filtered and afterwards dried four days on sheet-iron plates, over a very small fire. It was then passed through a 6 × 6 sieve, and weighed 291 pounds avoirdupois.

Six samples were then taken and portions *at once* weighed for assay. The reason for weighing for assay without loss of time was that the little remaining moisture might be exactly the same in the assay portions as in the main lot.

The assay results were 18.791 per cent., 18.857 per cent., 18.923 per cent., 18.906 per cent., 18.877 per cent., 18.767 per cent.

We have, therefore, 291 pounds precipitate, assaying 18.852 per cent. = 54.859 pounds pure silver. The silver contained in the roasted pulp which entered the vat was 57.197 pounds, and of this we obtained 95.91 per cent. The loss was 2.338 pounds of silver = 4.09 per cent. Judging by the check-samples of tailings which have so far been withdrawn from vat, this result appears slightly high.

For the purpose of ascertaining the ley (fineness) of this precipitate as it would enter the cupelling furnace, after being partially roasted in a reverberatory, a small portion was roasted without stirring, in a shallow dish; the residue assayed 26.032 per cent. silver. There will be very little expense in refining this substance; the German cupelling furnace will probably be found more suitable than the English one for this purpose.

When our roasters become acquainted with the ore they will be able to use much less salt, and the first leaching for removing soluble salts of base metals can be used. Of late we connect a piece of hose to the water-pipe and allow some three feet of its extremity to lie on the slag, the vat being then filled with ore. As water enters, some is allowed to escape through the spout. In this way the water least saturated with common salt flows away first, and the more saturated portions, on their descent, are diluted, depositing the silver chloride in the ore. It will be remembered that silver chloride is soluble in a strong solution of common salt, but is precipitated on diluting that solution. After washing a few hours in this manner, the excess of salt is removed, the hose is then pulled away, and the wash completed by allowing the water to enter on top.

Besides the points of detail referred to in the first leaching, there are certain points of management in the second leaching (that with calcium hyposulphite) which also conduce to great economy of material and to close extraction of silver in a very marked degree.

The samples taken from the whole pile of tailings, after discharging the large vat, assayed:

	18	milles =	5.2	ounces	per ton of	2000 pounds.
	18	"	5.3	"	"	"
	19	"	5.4	"	"	"
	18	"	5.2	"	"	"
	18	"	5.3	"	"	"
	18	"	5.2	"	"	"
	18	"	5.3	"	"	"
	17	"	5	"	"	"
	18	"	5.2	"	"	"
	19	"	5.4	"	"	"
Average,	18	"	5.3	"	"	"

They were twice weighed:

First weight, . .	23,395	pounds.	
Deduct, . . .	6,387	"	= (27.3 per cent. moisture).
	17,008	"	
Second weight, .	23,335	pounds.	
Deduct, . . .	5,554	"	= (23.8 per cent. moisture).
	17,781	"	

We have, consequently, 17,394 pounds of tailings, assaying 0.018 per cent., which gives a silver content of 3.131 pounds, and the pure silver which entered the vat being 57.197 pounds, we have a loss of 5.47 per cent., and this corresponds moderately well with the 4.09 per cent., which was shown by calculating the pure silver contained in the precipitate obtained.

Discussion.

Mr. C. A. Stetefeldt, New York: The first thing we may note in this paper is that an ore was treated here containing 33.78 per cent. of carbonate of lime. It has generally been assumed that silver ores, which contain such a large percentage of lime, could not be successfully chloridized, and especially not amalgamated, and also not successfully leached. I am inclined to believe that the analysis, as given here, does not represent the character of the ore which was treated on a large scale. The carbonate of lime in roasting is partly converted into sulphate of lime and partly into caustic lime, and caustic lime has a tendency to decompose chloride of silver and form metallic silver. Caustic lime, as well as other alkalies, has an injurious effect in leaching and in amalgamation.

I further remark that this analysis figures up exactly one hundred, and the silver is left out entirely. This is characteristic of Professor Price's analytical work (of which I had occasion frequently to see samples), that it always figures up exactly one hundred. And I suppose it is necessary in the West, because people would not be satisfied if the total per cent. was not exactly one hundred.

In making a chlorination test of the samples, I see that Mr. Clemes uses a boiling concentrated solution of hyposulphite of soda. These chlorination tests are generally made with a cold solution, or at least with a moderately warm solution. It is also generally assumed that, in subjecting a sample of roasted ore to a chlorination test, only the chloride of silver is dissolved. This is not exactly true; especially, if a warm solution of sodium hyposulphite is used, a great deal of silver is dissolved which is present in the metallic state. Mr. Russell, assayer at the Ontario mill for some time past, has investigated a great many chemical reactions of the leaching process, and has made especial experiments in regard to the solubility of different silver compounds in the hyposulphite solution. He finds that, while a cold solution—say a solution at 15° Celsius—dissolves a comparatively small amount of metallic silver, a solution which is heated to 75 or 50 degrees dissolves more than three times as much; so that, where we use a hot solution in the chlorination test, we not only get into solution the chloride of silver, but also metallic silver. And, furthermore, Mr. Russell found that also silver arsenate and antimonate are soluble in the hyposulphite solution, showing that really in all these tests it is not correct to speak of a chlorination test, but that it ought to be called a lixiviation test.

I have no doubt that, in roasting this ore, a great deal of metallic silver was really formed by the lime and went into solution in the leaching process. But, at the same time, I repeat that it seems to me doubtful that these results could have been obtained if the whole lot of ore treated contained over thirty-three per cent. of carbonate of lime.

Dr. T. Egleston, New York: I have read this paper with some interest, mostly because at present leaching appears to be the only process applicable in the case of poor ores, especially those containing the base metals. So far as my own personal experience goes, these conditions are applicable to almost any low-grade ore, unless it contains a very large amount of lead, and so applicable to a large class of ores that cannot be treated in any other way.

I wish particularly to speak of the great tendency there is in the West to use too much salt. Too much salt, or more salt than is required, is a disadvantage. First, because its use increases the cost; and, secondly, it is a positive disadvantage in the lixiviation. A very ingenious process has been invented by Mr. Hoffmann, of washing with the hot water from the under side. By thus introducing the hot water from the bottom, all the excess of salt is carried up, dissolving the silver as it goes. Then coming in contact with a great excess of water, the silver is precipitated on the top, and is left there as a crust, which contains almost all the silver which was dissolved.

I notice in this paper that the leaching was done from the top, and consequently all the extra salt went to dissolve out the silver, which must be precipitated from the leaching liquors. The bottom-washing is a very ingenious contrivance to prevent this, to which special attention needs to be called. Where an excess of salt is used, and the leaching is not done from the bottom, and the washing-water comes down through the ore, a considerable quantity of silver is found with the base metals precipitated. Where it is done from the bottom the silver is precipitated towards the top of the vat. A bullion which is comparatively pure is produced, as well as base metals from pure silver.

I would like to ask Mr. Stetefeldt with regard to the results from his chloridizing furnaces. My own experience is with revolving furnaces that are eight feet long.

Mr. Stetefeldt: The experiments which have been carried out lately by Mr. Russell, at the Ontario mill, give on an average from 93 to 94 per cent. of the silver extracted by lixiviation with Rus-

sell's solution, while the average by the ordinary hyposulphite solution is only about 90 to 91 per cent. Some very curious experiments have been made in roasting Ontario ore in the Stetefeldt furnace without any salt. The feeding of salt, which is crushed separately, was completely suspended, and the furnace was run for three hours without salt. After discharging the ore it was left hot for twelve hours on the cooling-floor. About 89.7 per cent. of the silver was lixiviated from this ore by Russell's process,—a part of which, namely, 17 per cent., was present as sulphate of silver, which would be extracted by water. Then about four or five per cent. was present as native silver, and the rest as antimonate and arsenate of silver. From fahl-ore, which forms the principal silver-bearing mineral of the Ontario ore, and contains both antimony and arsenic, the last-named combination resulted. The way that this experiment on a large scale came to be made was this: I asked Mr. Russell to roast different ores in the muffle (oxidizing), and then try the effect of his new solution. About the composition of the latter I can say nothing here, because Mr. Russell's patents have not yet been granted. He took samples from the Ontario mine, from the Manhattan mines, from the Lexington mine, and from several others, and roasted about a pound of each in the muffle. The roasting was continued for half an hour, one hour, one hour and a half, two hours, two hours and a half, and three hours. A most remarkable fact was established in leaching these roasted samples, namely, the longer the roasting continued the less silver could be leached out. For instance, after half an hour he leached out thirty-one per cent., and after three hours he leached out only eight per cent. In another case, after half an hour he leached out sixty per cent., and after three hours only about five.

It appeared, from these tests, that the results were principally a function of time consumed in roasting. Hence the experiment on a large scale in the Stetefeldt furnace was carried out.

Mr. Russell made this experiment in the Stetefeldt furnace at a very high temperature, and I have advised him to repeat it at a moderate temperature. The muffle-experiments were also carried out in two ways, one series of experiments at a low red heat, and another at a cherry-red heat; and in every instance the high temperature had an injurious effect upon the extraction of the silver, and a low temperature had a beneficial effect. I have no doubt that, by roasting at a moderate temperature, he will be able to extract 93 or 94 per cent. of the silver.

Dr. Egleston: There is another very curious thing about roast-

ing with salt. In most ores the less salt that is used the better. There is a great gain in using a minimum amount of salt, and then leaving the material on the cooling-floor, as it has been found that chlorination continues in the heap long after it has left the furnace.

Mr. H. M. Howe, Boston: In oxidizing, as well as in chloridizing, roasting the decomposition of sulphurets goes on after they have been withdrawn from the furnace; and if they are heaped together, so as to keep hot, we find that after the lapse of a few hours the amount of undecomposed sulphurets has materially decreased. This is, no doubt, due to the reaction of sulphates, and even of oxides, upon the sulphur of the undecomposed sulphurets yielding sulphurous acid and a low oxide of the metal; the sulphuric acid and the previously formed oxides, which thus react on the sulphurets, being reduced to a lower state of oxidation.

In some oxidizing roasts in an open reverberatory, on previously kiln-burnt Spanish pyrites, I found that the amount of copper existing as undecomposed sulphuret was diminished by 0.7 per cent. while the ore was cooling in a heap outside of the furnace, the total copper contents being only about eight per cent. On this account it is very desirable to have pockets under or beside the furnace, where the ore can be kept hot for a long time after drawing.

Mr. Stetefeldt: As far as the use of salt is concerned, that is exceedingly different with different classes of ores. I have succeeded in roasting ore with about two and a half per cent. of salt, but with most ores such a low percentage is entirely insufficient. For instance, we have carried out a series of experiments at Ontario to determine the percentage of salt necessary. Five per cent. of salt has no effect whatsoever. It is simply consumed without chloridizing the silver. Good chlorination only commences with ten per cent. of salt, and chlorinations in the nineties cannot be obtained with less than sixteen per cent. and more. Since at the Ontario mill salt costs only eight dollars per ton, one per cent. of salt forms no item, and it has been found of advantage to use a surplus of salt.

Dr. Egleston: I believe that in most cases, if the salt was reduced 50 per cent., there would be a gain of 15 to 20 per cent. in the chlorination.

Mr. Stetefeldt: As far as the loss of silver is concerned in the leaching process, caused by the wash-water, that loss will vary according to the quantity of undecomposed salt in the ore, and whether hot or cold water is used. In Russell's experiments with Ontario ore, about three-tenths of one ounce of silver per ton of ore was lost

in the wash-water. A large portion of this silver was regained by treating the first wash-water, containing also copper, with scrap-iron. Cement-copper was precipitated with about 200 ounces of silver per ton.

DR. EGLESTON: Leaching from the bottom?

MR. STETEFELDT: From the top.

THE DETERMINATION OF MANGANESE IN SPIEGEL.

BY G. C. STONE, NEWARK, N. J.

AT the conclusion of my paper on the same subject read at the Boston meeting of the Institute, I offered to send some of sample No. 2 to any chemist who wished to analyze it. Eight chemists wrote to me for samples; so far I have received results from five. I give these results in a table (on the following page), together with the results previously obtained:

As to the chemists and their methods: *K* is an iron-works chemist whom I only know by correspondence; he writes: "No. 27 (13.64) was obtained by the method I generally use, as follows: Dissolve 0.8 grams spiegel in hydrochloric acid and a little potassium chlorate, in a half-liter flask. Boil off most of the acid, add ammonia in slight excess, redissolve in acetic acid, using rather more than is really necessary, and then add 8 or 10 grams of sodium acetate and make up to the mark with warm water. Boil hard for fifteen minutes, then allow to settle (cool?), until the liquid reaches the mark, and withdraw 300 c.c. of the nearly clear liquid. Add to this an excess of hydrochloric acid, evaporate to dryness, take up with hydrochloric acid and water, and separate the iron by two precipitations with ammonia (I have often tested the ferric hydrate for manganese, but have never found any, if the separation by ammonia was properly made). Finally, precipitate the manganese as phosphate." Nos. 28, 29 (13.35, 13.07) were by Ford's method.* No. 30 (13.50) was by Troilus's method.† He writes, "I may add the results are quite as good as I expected, although for any element except manganese, they are not close enough for anything like accurate work."

L is a firm of commercial chemists of large experience who have made a specialty of iron work. Their method is as follows: Dissolve

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* Transactions, American Institute of Mining Engineers, vol. ix, p. 397.

† Ib., vol. x, p. 173.

TABLE I.

Sample No. 2.

Chemist	No.	Manganese found	Method used
A	1	12 92	Acetate, bromine, and phosphate.
A	2	12 96	
B	3	13 38	" " " "
B	4	13.44	
B	5	13 53	Acetate and phosphate.
B	6	13 68	
B	7	13 50	Potassium chlorate and phosphate.
B	8	13 58	
C	9	13.52	Potassium chlorate and oxalic acid.
C	10	13 68	
D	11	14.18	Acetate, bromine, and carbonate.
D	12	14 56	" " " "
E	13	13.46	" " " phosphate (average).
F	14	14.41	" " " ammonia.
G	15	14.47	Acetate and bromine, and carbonate.
H	16	12 60	Potassium chlorate and oxalic acid.
H	17	12.72	
H	18	12.86	" " " " "
I	19	12.20	" " " " "
I	20	12 44	
I	21	12 92	" " " " "
I	22	13 05	
I	23	12.81	Same method, zinc added.
I	24	12 91	" " lime added.
I	25	10 36	" " alumina added.
J	26	12 95	Potassium chlorate and oxalic acid.

NEW RESULTS.

Chemist	No.	Manganese found	Method used
K	27	13 64	Acetate and phosphate.
K	28	13.35	Potassium chlorate and phosphate.
K	29	13.07	
K	30	13.50	Acetate, bromine, and ammonia.
L	31	13.13	Barium carbonate, potassium permanganate.
L	32	13.17	
M	33	13.70	Potass. chlorate, acetate, bromine, carbonate.
M	34	14.00	" " " " "
N	35	13.66	Acetate, bromine, and phosphate.
N	36	14.20	
N	37	13.65	Potassium chlorate and phosphate.
N	38	13.68	
N	39	13.84	
N	40	10.76	Potassium chlorate and oxalic acid.
N	41	10.82	
N	42	10.82	
O	43	12.97	Acetate, bromine, and phosphate.
O	44	12 93	
O	45	13.18	Potassium chlorate and phosphate.
O	46	13.21	

0.5 grams spiegel in 10 c.c. nitric acid (1.20 specific gravity), by heating; cool, dilute, and precipitate the iron by barium carbonate, add a considerable excess of barium carbonate (to help the precipitated MnO_2 settle), titrate with potassium permanganate, which has been standardized by oxalic acid; 1 c.c. of the permanganate used contained 0.00199 grams manganese. They also analyzed separately portions of the sample sent them which would and would not go through very fine bolting cloth with the following results:

No. 1. 14 05 per cent. Mn.	No. 5. 12 418 per cent. Mn.
" 2. 14 05 " " "	" 6. 13.134 " " "
" 3. 14.205 " " "	" 7. 13 174 " " "
" 4. 13.134 " " "	

Nos. 1, 2, and 3 passed through the bolting cloth; No. 5 would not go through; No. 4 was "0.25 grams coarse, 0.25 grams fine;" and Nos. 6 and 7 were just as the sample was received. They write, "These results we think will explain the discrepancies in the results you have obtained from other chemists." This is a conclusion in which I cannot fully agree, for the following reason: the results are what I should have expected, as the low grade spiegels are always harder and more difficult to pulverize than the high grades, and it is impossible to get a sample, even from a single casting, in which the coarse and fine parts are of the same composition. Knowing this, I had the entire sample sifted through a forty-mesh seive before dividing it, and took great care to give each chemist a fair proportion of coarse and fine; and it will be seen that the low results are mostly by one method, the medium by another, and the high by a third, so that I hardly think L's results will explain anomalies.

M is an iron-works chemist; his method is as follows: Precipitate the manganese by potassium chlorate from a concentrated nitric acid solution, dissolve in hydrochloric acid, separate all iron as basic acetate twice, then precipitate the manganese by bromine, dissolve, precipitate by sodium carbonate, and weigh as Mn_3O_4. He writes, "I have not my note-book at hand," so cannot be positive as to the results.

N is an iron-works chemist of several years' experience; he writes, "Results Nos. 35, 36 (13.60, 14.20) were obtained by precipitating with sodium phosphate after making two basic-acetate separations in the old way; I am not satisfied with them. Results Nos. 37, 38, 39 (13.65, 13.68, 13.84) were obtained by the method I generally use, as follows: The spiegel was dissolved in concentrated

nitric acid, and the manganese thrown down with potassium chlorate. After washing, tested filtrate for manganese, and found none. Then washed the asbestos into a beaker, and added dilute hydrochloric acid and a few drops of sulphurous acid, and the manganese went into solution at once. Boiled off the sulphurous acid, filtered out asbestos, added a few drops of nitric acid, boiled and added a large excess of ammonium chloride and ammonia, heated a few minutes, filtered, dissolved the precipitate and repeated the operation. In the combined filtrates the manganese was precipitated as phosphate as usual. Results Nos. 40, 41, 42 (10.76, 10.82, 10.82) were by Williams's method, and I can only say that I worked it as carefully as I could, and took every precaution, with but little success, as the results show."

O is an iron-works chemist; his results, Nos. 43, 44 (12.97, 12.93), were obtained by dissolving in nitric and hydrochloric acids, evaporating to dryness, redissolving and filtering out the silica, precipitating as basic acetate twice, using a large excess of acetic acid, then by bromine, dissolving the precipitate in hydrochloric acid, and separating the small amount of iron present by precipitating with ammonia and sodium acetate twice (the precipitate was tested for manganese but contained none); finally the manganese was precipitated and weighed as phosphate. Results Nos. 45, 46 (13.18, 13.21) were by Ford's method, precipitating in 75 c.c. by repeated additions of nitric acid and potassium chlorate, diluting with cold strong nitric and cooling before filtering.

In all, there are forty-six determinations by fifteen chemists using ten methods; these methods may be divided into four classes, *i.e.* 1st. Williams's method. 2d. Other volumetric methods. 3d. Methods in which the manganese is precipitated and weighed as phosphate. 4th. Methods in which the manganese is precipitated as basic carbonate or hydrate in presence of large quantities of alkaline salts and weighed as Mn_3O_4. The results may be divided into, 1st, those below 13 per cent.; 2d, those between 13 and 14 per cent.; and, 3d, those above 14 per cent. If we so divide them, omitting Nos. 23, 24, 25 for obvious reasons, and arrange them, we will get the following table:

TABLE II.

	First class Williams's volumetric method.	Second class Other volumetric methods.	Third class. Methods in which the manganese is weighed as phosphate	Fourth class Methods in which the manganese is precipitated as a basic salt.	All methods.
Number of Chemists using method, . .	4	2	6	5	15
No. of determinations below 13 p. ct.	10	0	4	. . .	14
No. of determinations between 13 and 14 p. ct., . .	1	4	16	2	23
No. of determinations above 14 p. ct.	. . .	. . .	1	5	6
Per cent. below 13, .	91	. . .	19	. . .	33
Per cent. between 13 and 14, ...	9	100	76	29	53
Per cent. above 14, .	. . .	. . .	5	71	14
Highest, ...	13.05	13.68	14.20	14.56	14.56
Lowest, ...	10.76	13.13	12.92	13.50	10.76
Average, ...	12.19	13.37	13.42	14.12	13.21

From this we see that 71 per cent. of the results below 13 per cent. were by methods of the 1st class, 87 per cent. of those between 13 and 14 per cent. were by methods of the 2d and 3d classes, and 83 per cent. of those above 14 per cent. were by the 4th class. Some of the results must necessarily be wrong, and I think the above table will enable any one interested to form an opinion as to which results are probably wrong and to judge of the value of the different methods used.

A word as to the volumetric method used by C and myself. In my former paper I stated that, as the result of experiments there given, it was my opinion that when manganese was precipitated by potassium chlorate from a solution of *spiegel* in strong nitric acid, the manganese was not precipitated as pure MnO_2, but as a lower oxide, approximating $10MnO_2,MnO$ in composition. In a paper

read by Mr. Mackintosh at the Roanoke meeting, he attacks this conclusion, and gives some experiments which tend to show that the precipitate in question is pure MnO_2, and ends by saying: " . . that any estimation based upon the theory that the precipitate is not MnO_2 is of no value, because it is founded on false premises, and therefore can never be true, save by accident." Without questioning the correctness of Mr. Mackintosh's methods of arriving at this result (although I think there are reasonable objections to them), I would point out that this does not affect the method in the least, as it is not founded on any such theory. The only points assumed are, that the precipitate is of constant composition, to this all who have tried it agree; and that, when two or more chemists, working independently and by different methods on the same sample, get results which agree within very narrow limits, these results are accurate.

That these assumptions are reasonably correct I think is shown by the fact that we have never had a complaint of the quality of our spiegel since we have analyzed it by this method. We have analyzed in all over one thousand samples, most of the spiegel has been sent to our two most particular customers, one of whom will complain if he finds the spiegel more than one-half of one per cent. lower than we have stated it to be.

Discussion.

J. B. Mackintosh, New York: On reviewing the series of determinations presented in the paper before us, it seems to me that the most natural method of classifying the results is to group them, according to the percentage obtained, in the following divisions: 1st, those approximating 13.5 per cent.; 2d, those approximating 13 per cent.; 3d, those results with which the analysts were not satisfied, including two results which are obviously too high.

Before grouping them thus I wish to make some remarks concerning the results obtained by "I" (*i. e.*, myself). Experiments 19 and 20 were made in a great hurry, at the request of "H," from whom the sample was received, and to whom the reports were made. Not being satisfied with the results obtained, the analyses were repeated (Nos. 21 and 22) the next day, under usual circumstances of time and care. The sample in 19 and 20 was probably at fault. Experiments 23 and 24, in which chlorides of zinc and calcium were added, were perfectly normal, and the results are considered of equal value with 21 and 22. Experiment 25, in which alumina, in the form of potash alum, was added,

did not go well, owing to the formation of a precipitate of ferric or aluminic sulphate, which interfered with the process. The analysis was only finished out of curiosity, and the result (never intended for publication) showed nothing, save that potash alum interferes with the process.

In regard to results 9 and 10, obtained by C, it also appears to me, that, since their accuracy depends on the accuracy of the gravimetric methods which are here involved, they should not be considered in any discussion regarding the relative merits of such methods.

Taking these points into consideration, and classifying as above suggested, we will have:

I.

Chemist.	No.	Pr. ct	Av. pr. ct.	Method.
B	3	13.38	13.41	Acetate, bromine, phosphate.
B	4	13.44		
B	5	13.53	13.60	Acetate, phosphate.
B	6	13 68		
B	7	13 50	13.54	Chlorate, phosphate.
B	8	13.58		
E	13	13.46	13.46	Acetate, bromine, phosphate.
K	27	13.64	13.64	Acetate, phosphate.
K	28	13.35	13.21	Chlorate, phosphate.
K	29	13.07		
K	30	13.50	13 50	Acetate, bromine, ammonia.
N	37	13.65	13.72	Chlorate, phosphate.
N	38	13.68		
N	39	13.84		
Gen'l average,		13.52		

II.

Chemist	No.	Pr. ct.	Av. pr ct	Method.
A	1	12.92	12.94	Acetate, bromine, phosphate.
A	2	12.96		
H	16	12.60	12.73	Chlorate, oxalic acid, permanganate.
H	17	12.72		
H	18	12.86		
I	21	12.92	12.92	Chlorate, oxalic acid, permanganate.
I	22	13.05		
I	23	12.81		
I	24	12.91		
J	26	12.95	12.95	Chlorate, oxalic acid, permanganate.
L	31	13.13	13.15	Barium carbonate, permanganate.
L	32	13.17		
O	43	12.97	12.95	Acetate, bromine, phosphate.
O	44	12.93		
O	45	13.18	13.19	Chlorate, phosphate.
O	46	13.21		

Average of gravimetric results, ... 13.03
Average of volumetric results, ... 12.91
General average, ... 12.956

III.

Chemist	No	Pr. ct.	Av. pr ct.	Method.
D	11	14.18	14.37	Acetate, bromine, carbonate.
D	12	14.56		
F	14	14.41	14.41	Acetate, bromine, ammonia.
G	15	14.47	14.47	Acetate, bromine, carbonate.
I	19	12.50	12.32	Chlorate, oxalic acid, permanganate.
I	20	12.14		
I	25	10.36	——	Addition of potash alum.
M	33	13.70	13.85	Chlorate, acetate, bromine, carbonate.
M	34	14.00		
N	35	13.66	13.93	Acetate, bromine, phosphate.
N	36	14.20		
N	40	10.76		
N	41	10.82	10.80	Chlorate, oxalic acid, permanganate.
N	42	10.82		

Now we may dismiss the third class of results from further consideration, for, if the chemists who obtained them are of the opinion that they are not trustworthy, we can attach little or no importance to them in an argument.

In the first class we have four chemists, using four methods, all gravimetric, and all but one being alike in the final precipitation as phosphate. There are fourteen determinations, and of these only three are within a variation of 0.05 per cent. from the average, and six within a variation of 0.10 per cent.

In the second class we have six chemists using four methods, two gravimetric and two volumetric. There are sixteen determinations, and of these seven are within a variation of 0.05 per cent. from the average, and nine within a variation of 0.10 per cent.

Chemists A and O, working by a method calculated to eliminate all errors, have obtained results averaging 12.94 and 12.95, respectively. Now, if we had no other results, these would be accepted, unhesitatingly, as the correct percentage. These figures are closely confirmed by the volumetric results of I and J. No other method furnishes us with results so nearly identical as these.

These figures show a slight but decided preponderance in favor of the results averaging 12.95, for there is a majority of chemists, a majority of determinations, a greater number of close agreements, and a greater diversity in the methods employed, all of these points being on the side of the second class of results.

If it is correct to assume, "when two or more chemists, working independently, and by different methods, on the same sample, get results which agree within very narrow limits, that these results

are accurate," then it follows that the results averaging 12.95 per cent. are accurate, from the reasons given above, and necessarily, that the other results are inaccurate.

Mr. A. E. Hunt, Pittsburgh, Pa.: I have to confess myself as one of the firm whom Mr. Stone calls Chemist "L." I would like to qualify one of the statements that he has quoted from us, viz.: "that these results, we think, will explain the discrepancies in the results that you have obtained from other chemists."

We found that the fine portion sent us contained over one per cent. more manganese than the coarser portion, and we believe that, unless great care was taken to get an exact average of the sample for analysis, a discrepancy was thereby obtained, so that we would like to go on record as saying that "we think these results may explain some of the discrepancies."

Mr. Stone agrees with us that spiegel is not perfectly homogeneous, and that in crushing a sample the finer material would be likely to be richer in manganese than the coarser. Any one can see from the appearance of the fracture of spiegel that it is at least decidedly unhomogeneous in structure, and it is a fact that we have often demonstrated by analysis, that these different structures vary in manganese; and we have found, also, that this variation increases as the alloy is richer in manganese, so that in 80 per cent. ferromanganese great care has to be taken in selecting the sample.

I would criticise the comparison of all the results, as being very unfortunate in that the material was not crushed and put through a hundred-mesh instead of through a forty-mesh sieve.

THE COLORIMETRIC DETERMINATION OF COMBINED CARBON IN STEEL.

BY ALFRED E. HUNT, PITTSBURGH, PA.

Professor Eggertz first published a method based upon the fact that, when steel is dissolved in dilute nitric acid, and heated until the separated flocculent carbonaceous matter goes into the solution, the liquid assumes a brown color proportionate in intensity to the amount of the combined carbon in the steel. This method has been so variously modified that at present but few chemists use exactly the same procedure. It is the object of this paper to present

some of these modifications, and to point out some of the causes of error that are to be guarded against.

At the outset the following proposition should be borne in mind, for it is the golden rule of the color-carbon method, upon which hinges its accuracy. *Select color standards which shall be as nearly like the samples to be treated as possible, both as to chemical composition and mechanical treatment, and treat the standards and samples to be tested exactly alike in working.* A widely varying chemical composition in other elements than carbon and iron, and the mechanical treatment, as well as the varying modes of carrying on the analysis, all make differences in the intensity and shade of color given by combined carbon in steel to its nitric-acid solution. Hence, in choosing the color-standards to be used, not only must there be an approximation in percentage of combined carbon to the sample to be tested, but also as nearly as possible the same general chemical composition and mechanical conditions. This, and all other statements relative to standards, holds good equally where fixed standards of coloring materials are used, for these color solutions are simply matched shades, and represent what the actual steel standards exhibit, and, of course, should vary accordingly as the varying conditions change the shade of the steel solutions to which they correspond.

The mechanical state of division of the standard and sample to be treated must be about the same. Drillings are much to be preferred to filings for color-determination, not only on account of their being less liable to contain foreign matter, but, being coarser, they dissolve more slowly. Fine particles of steel, especially if they are rich in carbon, dissolve so rapidly in dilute nitric acid that unless especial precautions are taken to keep the solution cold, some of the carbon is oxidized and is lost in a gaseous form.

The older—and, I think, the still more generally taken—weight, is one-tenth of a gram, although varying amounts up to a gram are used. I prefer to take not over two-tenths of a gram for analysis, for though errors as to weight and homogeneity are less with the greater weight taken, still the lesser amounts are much more convenient to work with. The ordinary analytical balance is generally used for weighing. I weigh in an aluminium boat, 1¼ inch in diameter, dished to ½ inch in depth, with a convenient nose for conveying the drillings into test-tubes; it weighs 2 grams. In furnace-laboratories, subject to the jarring of hammers and machinery, to varying temperatures, and to considerable dust and dirt, a steel watch-spring balance with aluminium pan is better. The weighings

should always be checked, by first noting the level on the graduated scale to which the accurate weight brings the weighing pan or pointer, and balancing each sample of steel to this level. I have found a magnetized steel needle, of 4 inches length, very convenient for handling the drillings while weighing. Care should be taken that the tubes used are dry, and that no particles of steel remain sticking to the upper walls of the tubes.

Too little acid gives too dark color; thus, if only $2\frac{1}{2}$ c. c. of acid are used for $\frac{1}{10}$ gram of 0.80 per cent. carbon steel, the color imparted looks like a 0.90 per cent. carbon steel where 4 c. c. of acid is used. I use for each $\frac{1}{10}$ gram of steel up to 0.20 per cent. carbon steel, 2 c. c. of nitric acid of 1.20 specific gravity. From 0.20 per cent. carbon up to 0.50 per cent. carbon, 3 c. c.; from 0.50 per cent. carbon up to 1.00 per cent. carbon, 4 c. c.; from 1.00 per cent. carbon up to 1.75 per cent. carbon, 5 c. c.; above 1.75 per cent. carbon, 8 c. c.* A variation in the shade, and some little, too, in the intensity of the color is obtained by varying the way the acid is brought into contact with the steel. Some chemists prefer to pour the drillings slowly into the nitric acid; others to immerse the tubes or beakers containing the drillings into cold water, and then to pour the acid gradually on to the drillings, and still others pour the acid on to the drillings without taking any precautions as to uniformity of speed or temperature. This is a common source of error, especially where the carbon is high. I prefer to slowly, but steadily, pour the acid upon the drillings immersed in test tubes in cold water, as being the more simple and uniform method. At the laboratory of at least one Bessemer works they have a very convenient apparatus for forcing uniformly the weighed drillings out of little glass cylinders, by means of little wooden pistons, into the beakers of acid kept immersed in cold water.

The "C. P." nitric acid usually obtained in the market is of about 1.40 specific gravity, and by diluting to exactly one-half with distilled water gives very nearly 1.20 specific gravity; it is not necessary that the specific gravity be exactly 1.20, providing that the acid used at one time is of the same strength. The usual custom, which I think in most cases is safe enough, is to dilute the concentrated acid to one-half strength, pouring the acid into the water and shaking vigorously. The diluted acid should be kept in a dark glass bottle out of direct rays of sunlight. The nitric acid

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* Transactions Am. Institute Mining Engineers, vol. x., p. 179.

must be free from nitrous fumes, organic matter and chlorine. Only $\frac{1}{10}$ mg. of chlorine produces a distinct yellow color in a solution of $\frac{1}{10}$ gram of iron in 4 c. c. of nitric acid. Each newly made-up lot of nitric acid should be tested with silver nitrate.

The solutions must not be heated until all action has ceased in the cold, when the cold water in which the tubes are immersed is rapidly brought to boiling and boiled for fifteen minutes for soft steels under 0.15 per cent. carbon, for twenty minutes if between 0.15 per cent. carbon and 0.30 per cent carbon, for thirty minutes if between 0.30 per cent. and 0.80 per cent. carbon, for forty-five minutes if above 0.80 per cent. carbon. If the tubes are immersed at once into boiling water, after action has ceased in the cold, too violent action ensues, which may occasion loss. Heating for too long a time causes the solutions to become lighter. The higher the heat the more rapid the operation, and the darker the solutions will be after cooling and diluting. The boiling temperature is usually maintained, though for special reasons other temperatures are often used, the essential point being to maintain always the same temperature in all cases where fixed standards are used, and to treat the standard and the steel under examination at exactly the same temperature where steel standards are used. Sometimes a reddish-yellow deposit, consisting of nitric acid and oxide of iron, forms on the walls of the tubes, which makes the solutions turbid;* in such cases a low temperature of about 70° C. is preferable. The ceasing of the evolution of the fine gas bubbles from the clear solution is a good indication of the completion of the solution. The tubes should be shaken several times during the heating, and the iron salts should not be allowed to dry upon the walls of the tubes. It is well to prevent the too rapid evaporation of the water in the copper vessel by pouring some liquid paraffine upon it, though this makes the outside of the tubes disagreeably sticky. The color solutions during the entire operation must be kept out of direct rays of sunlight, as it rapidly fades them. The color fades much more rapidly after dilution with water.

I have found no difference in the color solutions when they are rapidly cooled down after heating, or are allowed to remain in the hot water and gradually cool with it. Where the carbons are low, they may be allowed to stand for two or three hours before diluting and comparing. Eggertz says that solutions of 1 per cent. carbon should not be allowed to stand for any length of time before

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* Transactions Am. Institute Mining Engineers, vol. x., p. 180.

comparison,* as they soon grow paler, and also become turbid with a precipitation of organic matter; although this can be to a considerable extent avoided by using a larger quantity, as 8 c. c., of acid in the first solution for each tenth gram taken. The 1.20 specific gravity nitric acid solution of color-carbon, after it has gone into solution, must be diluted with at least its bulk of water to get rid of the tint of oxide of iron. The color solution, after heating and cooling and diluting with one-third its volume of water, can be filtered from graphite, etc., through an ordinary dry paper filter, without altering the color.

Tubes for comparison must be of exactly the same internal bore and thickness of glass walls, of colorless glass, and, where calibrated, the scale must be corrected with an accurately calibrated burette, as errors are often found of considerable importance. The diameters of the calibrated tubes for comparing vary. I prefer to use tubes of not over $\frac{1}{2}$ inch internal diameter, for though the body of the solution to be looked through is rather small, still they can be read more accurately than larger tubes. The point of reading is another matter of individual preference. Some prefer to read to the upper border of the fluid, others to different portions of the meniscus. At least one minute should be allowed for the liquid to run down the walls of the tube before the final reading.

In comparing the colors, it is usual to hold a piece of thin, clear white paper behind the tubes. It is natural to most eyes to have the left-hand tube appear slightly the darkest. A good way is to match the colors so that either tube, as it is reversed, will appear darkest when it is placed to the left. This appearance can be corrected by holding the tubes a little to the right. I prefer to match the colors by holding the tubes inclined away from me over a large flat plate of white porcelain, at an angle of about 45° with the plane of the slab, when seated at a table facing a window. I also use with advantage a camera-shaped box, painted black inside, open at one end to look into, and having a frame hinged at the bottom, which is covered with thin white paper to form a background for the tubes. Near this end an opening in the top of the frame and a gutter in the bottom allow the tubes to be placed. This arrangement I have found especially useful in the night-time, when I use a fixed Bunsen gas burner, in which a bead of carbonate of soda on a platinum wire gives a monochromatic flame. It is placed in such a position as to have the rays reflected, by means of the hinged frame

* Transactions Am. Institute Mining Engineers, vol. x., p. 183.

of paper at the back, upon the tubes. I have been enabled, in this way, to read color carbons with much ease—in fact, I prefer to compare them by this means than by daylight, as the light is always under control, and no outside rays interefere with lights and shadows. I have used this apparatus in making quick tests at open-hearth furnaces.

Good work can be done, and where many samples are to be tested every day, as in Bessemer works, it is very much more conveniently and rapidly done by simply matching the diluted test with a rack of permanent standards. Still, I prefer, in cases where color carbon analyses are only occasionally made, to use color standards of steel with each lot of samples to be tested, since whatever variation in color due to manipulation occurs will be borne by the standards as well, and the errors occasioned thereby checked in proportion as the standards are near in character to the samples to be tested.

Permanent standards of organic substances, as burnt coffee, burnt sugar, anilines and the like, are not satisfactory, at least so far as I have worked with them, but the mixture described by Eggertz in his paper in the *Jernkontorets Annaler*, and translated by Mr. Magnus Troilius, I have found to work very nicely and to give permanent standards. I proceed as follows: Dissolve and thoroughly mix 5 grams of neutral ferric chloride in a mixture of 50 c. c. of water and 1½ c. c. of concentrated hydrochloric acid; dissolve and thoroughly mix 3 grams of neutral cobalt chloride in 50 c. c. of water and ½ c. c. of hydrochloric acid; dissolve and thoroughly mix 1 gram of neutral copper chloride in 20 c. c. of water and ½ c. c. of hydrochloric acid. Place in the color-tube a suitable amount of the light-yellow iron solution, and tone down the shade to the required brown with some of the cobalt solution, and give the slight green tinge that is necessary by slight additions of the copper solution. Of course, more or less of the cobalt and copper solutions will be required according to the particular shade to be imitated. The solution can be made more deeply yellow by additions of hydrochloric acid drop by drop.

If all the foregoing conditions are accurately fulfilled, the shade and tints can usually be well matched; however, it is sometimes impracticable to make the conditions of the sample and standard alike, due to some peculiarity of the composition of the steel or its treatment. This is especially the case with steels low in carbon; where slight variations in the conditions produce wide variations in the shade of color produced. In such cases a method first described

by Mr. J. E. Stead before the Iron and Steel Institute of Great Britain can be advantageously used. The scheme is as follows: One-half gram each of the steels is dissolved in 10 c. c. of 1.20 nitric acid in flat-bottomed flasks with marks of 60 c. c. of volume at 16° C. on the necks. Care is taken to keep the flasks cool by immersion in cold water, that the first action is not too violent. When the action has ceased in the cold, rapidly bring the water in the bath surrounding the flasks up to boiling, and keep at this temperature from ten to thirty minutes, according to the amount of carbon in the samples. Then dilute each sample with 30 c. c. of hot water and add 15 c. c. of caustic soda solution of 1.27 specific gravity, and allow to stand and cool, adding first, however, cold water enough to bring the line of the liquid nearly up to the 60 c. c. mark after contracting in cooling. When cold, correct the volume to exactly 60 c. c., and, if necessary, stir the solutions till homogeneous. Filter through a dry filter into graduated tubes, and take the first 15 c. c. of the filtrates for comparison. The combined carbon imparts a color about two and a half times stronger to the caustic soda solution than it does to the nitric acid solution, and the colors match in shades and intensity after solution, according to the proportion of combined carbon, irrespective of the peculiarities of the steels themselves. This method gives very accurate results, and the standards, when not exposed to direct rays of sunlight, keep a long time. The influence of chlorine is as fatal in this process as it is in the ordinary method. By this process, very low percentages of carbon can be determined with accuracy, and the standards need not be as close in composition to the unknown as in the other method.

Often in the open-hearth steel process, only a few minutes can be allowed for the determination of the carbon in tests taken from the furnace. In carbons below 0.25 per cent. a very accurate determination can be had by simply dissolving samples of $\frac{1}{0}$ gram each of the drillings, sifted through meshes of 10 to the inch, in 2 c. c. of 1.20 nitric acid in test-tubes of exactly the same size and color and thickness of walls, and by treating the sifted standards (chosen by the appearance of the fracture of the test) in exactly the same manner and at the same time, and then judging of the variation in colors at the moment of complete solution and before the carbon begins to separate out. Results can be easily got in this way in three minutes. When the carbon is over 0.25 per cent. it is best to have the nitric acid heated in a water bath to 80° C., and to use the same precautions as to having the drillings of about the same degree of

fineness and the tubes of the same size, etc. The drillings are dissolved in 4 c. c. of nitric acid, and as soon as the violent ebullition has ceased, immediately boiled, by holding the tubes on a hot plate, or directly over the flame of an alcohol lamp. For a 0.75 per cent. carbon steel it takes four minutes' boiling to completely dissolve the carbon, and by allowing three minutes to cool in cold water, the solutions are ready to decant into the measuring tubes and to dilute and compare. The color solutions prepared in this way are of course much darker; an 80-carbon standard steel by this quick method would read at 1.10 per cent. carbon compared with the same standard made in the usual way and boiled for thirty-five minutes. With skilful treatment in making all the conditions uniform, the same drillings can be made to give the same color every time, and a sample compared with a standard treated at the same time can be read in less than ten minutes after the drillings are first obtained, and this for any steels up to 1 per cent. carbon. Of course the accuracy of this method depends upon having the standard very near in composition to the sample to be tested. A sufficient number of weighed amounts of the standard drillings are prepared beforehand, and a sufficient supply of clean, dry tubes are kept in readiness for this quick test work.

Eggertz says the mode in which the carbon is present in the steel as "cement carbon" or "hardening carbon," renders the solution less dark in the latter case where the carbon is more intimately connected with the iron.* The writer's experience on this point is, that this is the most serious—in fact, almost the only uncontrollable—error in the color carbon method. Without knowing in just what condition the carbon exist in a sample of steel, it is impossible to choose with certainty a standard for exact comparison. The writer finds that the *mechanical* process of hardening alters *chemically* the condition of the carbon contained in steel, and that, so far as his experience goes, there is not a uniform but an irregular change produced in this respect by hardening. An equal weight of drillings of *the same steel* always gives lighter color to the nitric acid solution after hardening; but this difference varies, the results indicating from five to thirty per cent. less of carbon by color than actually exists in the steel as shown by gravimetric methods. In the few experiments which the writer has so far found time to make, he has found that this loss of color has been nearly restored by carefully annealing the hardened steel.

* Transactions Am. Institute Mining Engineers, vol. x., p. 183.

SOME NOTES AND TESTS OF AN OPEN-HEARTH STEEL CHARGE MADE FOR BOILER PLATE.

BY ALFRED E. HUNT, PITTSBURGH, PA.

THE charge to be described was made in a seven-ton furnace, with a hearth twelve feet long and eight feet wide, with three gas and three air ports on each side.

The stock of the entire heat was charged cold in one hour and five minutes, a part of the pig being first placed upon the bottom to protect it, then upon it the plate-scrap and blooms, and finally the remainder of the pig—some two thousand pounds.

In five hours and twenty-five minutes after beginning the charge the metal was melted down level, and two hundred pounds of hot twelve-per cent. spiegel was charged, care being taken to have it entirely immersed in the bath. In two hours more the bath was thoroughly melted and hot, and began to boil, *i. e.*, the carbon began to be oxidized and evolved through the bath of covering slag as carbonic acid and carbonic oxide gases. Seventy-five pounds of lumps of Republic specular iron ore were added at this time, increasing the action, so that in ten minutes after the metal was in active ebullition. A test of the metal showed it to have about 0.90 per cent. carbon. One hour after the first ore was added a test was again taken, after thorough rabbling of the metal, and it was found to be 0.37 per cent. carbon. One hundred pounds more of lump Republic ore and about seventy-five pounds of limestone were then added, and fifty minutes later, after the bath was thoroughly rabbled, a test showed the metal to have 0.23 per cent. carbon. Twenty-five pounds more of Republic iron ore were added and the metal allowed to boil for twenty minutes, when a test, after rabbling, showed the carbon to be 0.18 per cent. and the manganese to be 0.01 per cent.; the slag fracture was vitreous and of a very dark-green color.

About forty pounds of limestone were added, and, the metal being hot and in a state of quiet ebullition, a hickory pole of twelve feet length and about four inches diameter, was run through the aperture in the centre door and held in a steady inclined position in the bath, with the end touching the bottom, the pole being shoved in further as it was burned away. The bath was carefully watched to see that the action that ensued was not too violent, the pole being several times

pulled out to check the splashing of the metal. This "poling" of the metal lasted for about ten minutes. Ten minutes was then allowed for the bath to quiet down, when, after rabbling, two tests taken in different places in the furnace, showed between 0.14 per cent. and 0.15 per cent. in carbon. The metal was hot, and rapidly cut off a hook of inch iron in the bath, leaving no steel but only slag caught on the hook, on cooling the sharp pointed end that was withdrawn from the furnace. The furnace test of $1\frac{3}{4}$ by 1 by 5 inches long, showed a good clear silvery fracture, which had to be indented by a chisel for about $\frac{3}{8}$ of an inch on each side before giving way to the blows of a heavy sledge. The final addition of 150 pounds of seventy-two per cent. ferro-manganese was then added, the metal was thoroughly rabbled and tapped into the ladle just twenty-five minutes after the pole was taken out of the bath, and nine hours and twenty minutes after the first piece of stock was charged. The metal was cast into a hot ladle, and was bottom-poured into four plate ingots 7 inches thick by 37 inches wide by 48 inches long, and weighing about 3300 pounds each; and one ingot 18 inches square and 48 inches long, on the same group, weighing about 4000 pounds; and one ingot 7 by 15 by 22 inches, weighing 630 pounds; and one 12-inch square ingot, weighing 1620 pounds, which was top cast. The charge yielded 19,430 pounds of sound ingots, or 92.35 per cent. of the charge, 600 pounds of runners and scrap, or 2.85 per cent. of the charge, and 1010 pounds loss, or 4.80 per cent. of the charge. Two hundred pounds of Republic ore were used in reducing the bath, and 115 pounds of limestone to clear the slag of metal.

The charge consisted of

Number One charcoal Titan pig-iron,	6,080	pounds.
Open-hearth plate scrap,	4,510	"
Chateaugay blooms (62 in number),	10,100	"
12 per cent. German A U spiegel,	200	"
Weight of original bath,	20,890	"
Final addition of 72-per cent. ferro-manganese,	150	"
Total charge,	21,040	"

The analysis of the finished metal and of the constituents of the charge is as follows:

	Carbon.	Manganese	Silicon	Sulphur.	Phosphorus	Copper.	Silica.	Carbonate of Lime.	Iron.
	per ct	per ct	per ct	per ct	per ct	per ct	per ct	per ct.	per ct
Furnace test of Finished Steel at tapping,	0.15	0.41	0.020	0.023	0.033	0.023			
Drillings from Rolled Plate,	0.15	0.29	0.021	0.025	0.037	0.025			
Plate Scrap used in the charge,	0.15 to 0.18	0.25 to 0.35	0.025	0.025	0.040	0.025			
Chateaugay Blooms used in the charge,	0.10 to 0.30	none	0.013	trace	0.015	none	Slag 25-50		
No. 1 Titan Charcoal Pig used in the charge,	3.75	0.112	1.958	0.006	0.050	none			
12 per cent. German A U Spiegel used in the charge,	4.60	11.290	0.050	trace	0.076	0.310			85.50
72 per cent. Ferromanganese used in the charge,	5.08	68.520	0.062	trace	0.226	0.138			26.15
Republic Iron Ore used in the charge,		0.144		0.070	0.030	0.063	silica 1.393		67.80
Limestone used in the charge,		none		0.054	0.028	none	13.49	84.10	1.04

The carbon and manganese determinations were made of at least a dozen of the different samples that were tested mechanically, and they were found to be perfectly homogeneous, and to have carbon 0.15 per cent. and manganese 0.29 per cent. The carbon determinations were made by duplicate combustions, using the chromic-acid process described by Mr. A. S. McCreath,* previously separating the carbon with a saturated neutral solution of the double chloride of copper and ammonium. I use the drillings of this material for a 0.15 per cent. carbon standard in color analyses, and shall be pleased to send any member of the Institute who may desire it some of these drillings for analysis and comparison. The chemist of a Bessemer works made this same lot of drillings to be 0.10 per cent. carbon, and the chemist of an open-hearth works reported them to be "low, less than 0.10 per cent. carbon." In each case the results were obtained by the color method, and the errors were occasioned by their standards being correspondingly lower than mine; that is, this and other samples of steel which I make by gravimetric and color analyses to be 0.15 per cent. carbon correspond in color to their 0.10 carbon, as read by their standards.

In the following table of tests of this material, samples marked A were taken "with the grain," or with the longest axis of the test cut parallel to the longest axis of a plate rolled 135″ × 38″ × $\frac{1}{4}$″,

* Transactions American Institute of Mining Engineers, vol. v., p. 575.

from the bottom-poured ingot, 7″ × 15″ × 22″, weighing 630 pounds. Samples marked B were from the same plate, but cut transversely or with their longest axis parallel to the width of the plate. Samples marked C were cut with the grain of a plate rolled 150″ × 65″ × $\frac{5}{8}$″ from one of the bottom-poured ingots, 7″ × 37″ × 48″, and weighing 3325 pounds. Samples marked D were from the same plate as C, but were cut transversely to the grain. Sample marked E was from a small plate about twelve inches square, sheared from the same plate as were samples C and D, reheated and rolled down on a small sheet mill to a quarter-inch thick plate. Sample marked F was cut from a plate rolled from a slab of 12″ × 16″ × 5″, which had been reduced under a heavy hammer from the eighteen-inch square ingot, which had served as a central runner for the group of 3300 pound ingots, 7″ × 37″ × 48″. Samples marked G were taken from the same plate as samples A and B, but before the final dressing of the sample were heated red-hot and plunged into water, and then finished up with the file. Samples marked H were taken and treated the same as samples G, but were chilled in brine before final dressing. Samples marked I were taken the same as G, but were chilled in oil before dressing. Samples marked J were taken the same as G, but were heated red-hot, and then carefully annealed in ashes before dressing. Samples marked K were taken the same as G, but were heated red-hot, plunged into water, reheated gradually and equably, scoured, and the temper drawn at a dark-straw color before final dressing. Samples marked L were taken the same as G, but were heated red-hot, plunged into water, reheated gradually and equably, and the temper drawn at a blue color before final dressing.

The samples tested at the Watertown Arsenal and at Carnegie Brothers & Co.'s were from the same plate and were the same as samples marked A. Samples marked M were from the top-poured twelve-inch square ingot, hammered into a slab 12″ × 16″ × 5″ and then rolled to a quarter-inch thick plate.

Test A1 had 30 per cent. and A2 had 29½ per cent. of elongation at the moment of failure, that is, when the specimens failed to record any more pressure upon the scale of the machine.

In each of the specimens which I broke myself one of the broken ends was bent over upon itself double, through an angle of 180 degrees, with blows of a heavy sledge, and finally with a light steam-hammer, and in no case (including the specimens chilled in water, brine, and oil, and specimens from ¼″ to $\frac{5}{8}$″ thick) was there the slightest sign of rupture or shearing of the material.

Sample.		Thickness x Width.	Area.	Length of Section.	Breaking Strain.	Tensile Strength per sq. in	Percentage of Elongation.	Elastic Limit. Act-ual.	Elastic Limit. Pds per sq in.	Uniform Elongation.	Area at fracture.	Percentage of contraction of area.	Appearance of fracture.	Tests made by
				In.							Sq. in.			
A	1	.248 x 1.008	0 245	2	13500	56100	36					60	Silky.	Alfred E Hunt
	2	.242 x 1.005	0.243	2	13450	56350	35½					60	do.	do
A	3	.286 x 1.010	0 238	8	12500	52520	24.60					60	Silky.	Alfred E Hunt
	4	.245 x 1 017	0.249	8	14600	58634	27⅝						do.	Union Rolling Mills, Carnegie Brothers & Co.
	5	.245 x 1.017	0 249	8	14500	58282	26¼						do.	do do do
	6	245 x 1.017	0.249	8	14800	59437	24½						do	do do do
	7	.245 x 1.019	0.250	8	14610	58440	25¾						do.	do. do. do
A	8	.248 x 1.017	0.252	8	13460	53410	26.20	8850	35120	20	130 x .720 = 094	62.70	Silky with slight lamination.	Watertown Arsenal—Test Number 1891.
	9	.247 x 1.015	0.251	8	13700	54580	27.40	9100	36250	23	.130 x .700 = 091	63 80	do. do.	do. do. 1892.
	10	.244 x 1.016	0.248	8	13080	52740	23 70	8960	36130	18	130 x 710 = 096	61 30	do. do.	do. do. 1893
	11	.246 x 1 016	0.250	8	13750	55000	25 20	9480	37920	22	140 x .740 = .104	58 40	do do.	do. do. 1894.
B	1	.245 x 1 000	0.245	2	12980	52980	34⅜					56	Silky.	Alfred E Hunt.
	2	.245 x 1.000	0.245	2	12350	52450	35					56	do.	do.
C	1	.625 x 1.000	0 625	2	31900	51040	32					50	Slightly granular.	Alfred E Hunt.
	2	625 x 1.000	0.625	2	31900	51040	32¼					50	do.	do.
D	1	.625 x 1.000	0 625	2	31000	49600	30					48	Slightly granular.	Alfred E. Hunt.
	2	.625 x 1.000	0.625	2	31200	49920	30					47½	do.	do.
E	1	228 x 1.010	0.230	2	13390	58210	36					62	Silky.	Alfred E Hunt.
	2	.228 x 1.015	0.231	2	13450	58220	36½					62	do	do
F	1	.258 x 0 995	0.256	2	15300	59760	33					58	Silky.	Alfred E Hunt.
	2	.258 x 0.982	0.253	2	15300	60470	33					57½	do.	do.
G	1	.236 x 0.998	0.235	2	17100	72760	25					50	Laminated.	Alfred E Hunt.
	2	.238 x 0.994	0.236	2	18100	76690	25¾					50	do.	do.
H	1	.235 x 0.998	0 233	2	19800	84980	23 7/16					44	Granular	Alfred E. Hunt.
	2	.238 x 0 990	0 235	2	19500	82970	21⅞					42	do.	do.
I	1	.240 x 1 010	0 242	2	16350	67580	26					49	Slightly granular.	Alfred E. Hunt.
	2	.241 x 1.005	0.242	2	16400	67770	26					49	do.	do
J	1	.243 x 1.005	0.244	2	14300	58600	36½					61	Silky.	Alfred E Hunt
	2	241 x 1.010	0.243	2	14200	58430	36½					61	do.	do.
K	1	.241 x 1.000	0 241	2	16100	66390	27					52	Laminated.	Alfred E Hunt.
	2	.241 x 1.000	0.241	2	16000	66380	27					52	do.	do.
L	1	.241 x 1.000	0 241	2	14600	60580	32					58	Laminated.	Alfred E Hunt.
	2	240 x 1.000	0.240	2	14350	59790	32					57	do.	do.
M	1	.240 x 1.005	0 244	2	12480	52000	32					57½	Silky	Alfred E Hunt.
	2	.240 x 1.010	0.243	2	12600	52500	33					57	do.	do.

The above tests are too few to generalize upon, but they are all typical results which have been confirmed very many times, so that from them *as illustrations merely* I state the following propositions, which from a considerable experience in the data I believe to be true:

I. There is about 25 per cent. reduction in the percentage of elongation in the results of a specimen of soft steel of 8 inches between shoulders from those of 2 inches in length, and the percentage of elongation varies proportionately to the length of the specimens measured; hence figures as often given of the percentage of elongation, without stating the length of the specimens, are meaningless.

II. The percentages of elongation, measured at "*the moment of failure*," give from 15 per cent. to 20 per cent. lower results than those measured in the usual way, after the rupture, or as finally automatically recorded by the testing machine.

III. As steel is usually rolled with the most of the work in the direction of the length of the plate, specimens cut transversely to the grain of the metal in such cases give slightly lower results than those cut with the grain.

IV. Soft plate steel, of over one-half inch thickness, needs to be reduced from an ingot of at least nine inches thickness. A very important and often occurring cause of defective steel is that it has not had work enough, that is has not had sufficient reduction from the ingot to the finished steel.

V. An increase of from two to four thousand pounds per square inch, and a correspondingly lower elongation of from one to three per cent. in two-inch length sections of soft plate steel, is obtained by casting ingots twelve inches by sixteen inches in section, and hammering them to slabs of about five inches thickness, and then, after reheating, rolling these slabs into plate steel over plates of the same heat of steel, which are rolled directly from the ingot to the plate, or over ingots rolled to slabs and reheated and rerolled to plate, showing that there is a sort of hammer hardening in this soft steel, which the subsequent reheating and rolling does not entirely remove.

VI. Soft steel, of no matter how low carbon, can be hardened to a certain extent by being heated red-hot and plunged into water, and hardened more when plunged into brine, and less when quenched in oil.

VII. Soft steel of no matter how low carbon can be hardened,

and then the temper drawn to a certain extent, as can be easily proven by the testing machine.

VIII. If soft steel plates are finished at the rolls too cold, or are too suddenly chilled in the cooling down, a considerable decrease in ductility and increase in tenacity will be obtained between specimens from the plate without further treatment and specimens which have been carefully annealed before dressing.

IX. For soft plate steel bottom-poured ingots are more solid and uniform in structure, and yield much better plates than top poured ingots.

X. The percentage of carbon in steel for practical work is usually obtained by the color method. Outside of the errors of the method and errors of manipulation, including the personal equation of the operator in matching the colors, all of which I think in most cases are trifling, there is the great and common source of error due to the standard being erroneous. I question whether there are a half dozen laboratories in the country where the color standards would perfectly agree, so that before a general intelligent discussion of the properties of various kinds of steel can be had it will be necessary for the steel works chemists to agree more exactly as to their color standards for carbon determinations.

DIFFERENTIAL SAMPLING OF BITUMINOUS COAL-SEAMS.

BY DR. JAMES P. KIMBALL, LEHIGH UNIVERSITY, BETHLEHEM, PA.

In a paper which I had the honor to present to the Institute at the Montreal meeting, September 1879, I took occasion to refer incidentally to certain practical difficulties in the sampling of coal-seams (Trans. Vol. VIII., p. 181–3). This reference was particularly to the unequal distribution of sulphur in the form of pyrite, and to the necessity of discriminating between the several members or "benches" of a coal seam as to their relative proportion of visible sulphur.

What is a *practically truthful* estimation of the sulphur of a coal seam, is not *necessarily* the estimation of an average of sulphur in any given line of cross-section of the seam. Comparatively speaking, the range of sulphur in quantity is generally so low that errors in its determination, arising from neglectful sampling or from slips in the laboratory, fall chiefly upon this single ingredient. Not so,

however, with the ash. Unsuitable sampling of the coal-seam, or unsuitable preparation of the sample in the laboratory, often gives rise to errors in the determination of ash, so wide in range as to vitiate the analysis for all practical purposes, every other single determination, except that of moisture, sharing its ratio of the error. The truth is indeed, as I shall incidentally show, that indiscriminate sampling of bituminous coal seams opens the door to errors in the demonstration of *both* sulphur and ash, as the ratio of one generally follows the ratio of the other, from the association of slates rich in ash and pyritous sulphur. Hence, not only one but two sources of errors which give no sign of themselves, and for which no coefficients can be found. Distributed through an analysis, such errors become manifold to the extent of involving every single determination of essential parts. Serious mistakes thus arise in spite of every precaution that falls short of what I would call a *differential sampling* of the coal bed with reference to practical conditions which it is not always easy to ascertain.

No coal seam as a whole, nor any in more than a very few exceptional localities, presents a uniform cross-section of homogeneous coal. On the contrary, almost every breast of coal is constituted of two or more "benches" or divisions, separated by so-called partings which are sometimes simply divisional planes of bedding, and more frequently intercalations of clay slate or shale, bituminous or non-bituminous, pyritous or otherwise; or highly bituminous intercalations of so-called bone-coal passing into splint and cannel. Bedding planes are sometimes marked by the presence of fibrous coal (mother-of-coal or mineral charcoal), forming merely splitting surfaces; or else this substance may be of perceptible thickness, in the form of "bearing-in" courses or benches.

Bituminous coal often presents in a single breast a succession of benches of coal possessing widely different physical properties, on which depend their technical or practical qualities, no less at least than on their chemical constitution. Thus occur in portions of a bituminous coal-seam, if not indeed uniformly throughout its whole area, varieties of coal which, although only subordinate to a uniform type, admit of distinctions according to their physical properties, greatly facilitating technical operations, both in the mining of the coal-seam and in the application of the product. Whatever the use of such qualitative distinctions for technical purposes, it seems to me that they offer the means for a much closer and more accurate determination of the practical qualities of coal *in situ*—in advance of actual mining,

and for the solution of certain technical problems by dint of tiresome and often futile experience. Such differences occur in every coal bed, and often within very narrow limits, as, for example, within the compass of a single coal bank. Such differences arise from two separate conditions, namely: First, those governing the original deposition of the coal; and, second, those which have supervened since its deposition, including conditions such as depend upon its relations to the surface, and such as have followed as a result of displacement. Many of the former, while too minute for general description, should not escape the recognition of the sampler. Differences of the second class are mainly as to dip and cover. Differences in dip involve differences in the distribution of pyritous sulphur. Phenomena of secular weathering and of internal weathering (as the term was used by me in 1877, and as since widely used by Roth), closely follow differences in cover, or relations to outcrop.*

Among qualitative differences of the first class, to be more particular, the more important are the less obscure differences between coal seams of unlike physical characteristics, and between benches of unlike physical characteristics in a single seam.

The following may be mentioned: splint coal; cannel coal; lamellar coal; columnar coal; conchoidal coal; block (prismatic) coal; fibrous coal (mother-of-coal or mineral charcoal); friable coal, a common variety, characterized by fine cross-cleavage as well as by fine lamination. Seams, or the benches of a seam, are further characterized by the impurities which they contain, or by intercalations which separate them. These are chiefly laminæ of earthy sediments more or less bituminous, passing insensibly into slates, shales and clay on the one hand, and into bone-coal and splint and cannel coal on the other. These are often pyritous as well as bituminous, the pyrite sometimes being diffused, or again concentrated into segregations or lenses. Pyritous partings likewise occur within the sectional compass of the coal itself, arising from the crystallization of pyrite between surfaces of lamination or of cleavage. The presence of pyrite in coal may be under circumstances of approximately uniform distribution throughout an extended area, or an excess of it may be locally limited. Or again, an excess of it may take possession of a single bench, or confine itself to basin-like depressions or to a particular dip. Products of the weathering or oxidation of pyrite are found seated in place of the original sulphide, or transmitted into other parts of the coal by solution and percolation.

* See Extract from a Report of an Examination of Coal and Iron Lands adjoining Eastern Kentucky Railway, by the writer, Greenup, Ky., 1877, p. 3.

Benches of coal undistinguishable by strongly marked physical characteristics may nevertheless possess dissimilar technical qualities. While one bench may be a dry coal, another may possess good coking qualities; one may be highly sulphurous and another poor in sulphur. The sulphur of one bench may be in the objectionable form of pyrite, and in another bench in the innocuous state of an oxidized product of that mineral. In such cases the relative thickness of different benches becomes important. Thus partings of fibrous coal often dividing a coal-seam into benches, while seldom justly to be considered as an impurity, claim recognition by way of facilitating a discrimination between benches of a coal-seam, and rendering practicable a differential sampling of it in advance of mining—and even a quantitative determination of the true run of mine which, as I shall presently show, a sectional average of the whole coal-seam seldom affords.

Qualitative differences of the second class are always local. Such are cross-courses of fibrous coal, especially where not of too frequent or of regular occurrence, following some system of jointing or cleavage. Cross-courses of clay are obviously extraneous. It is also generally safe to regard as extraneous and adventitious light-colored clays, whether indurated or not, sometimes found as "slips" in rolls of a coal-bed under such circumstances as to indicate their intrusion as sediment by percolation into partings, or cleavage fissures opened by flexure.

Impurities, not in courses, or occupying divisions of bedding or lamination, such as minute laminæ or so-called "knife-edges" of slate, clay, bone-coal or fibrous coal; or such impurities as pyritous cleavages (flakes) or segregations of pyrite in lenses, are either local or persistent occurrences, and must be treated as essential parts of coal-seams or coal-benches accordingly,—that is, either locally or generally as the case may be, especially where their intermixture is either too minute or too extended to admit of separation either inside the mine or on the dump. Fibrous coal, whatever be its form of occurrence, is in mining operations generally dissipated in dust and screenings. As it is rich in fixed carbon and highly combustible, the effect of including in a sample a course of it, would be to raise the quality of an average. It should be excluded, however, on the ground that little if any finally enters into the actual product of a mine.

Thin benches of coal, bony coal, or slate often occur within the compass of a coal seam, and thus strictly belong to it, although not broken nor extracted in mining. Such are "top and bottom" coals

or slates, which, although ripped out in roads, headings and gangways for the sake of space in such road and main ways, are not removed from rooms at all, except in the case of top slates liable to fall, which for the sake of security to life are then likewise ripped in rooms subsequent to the extraction of the coal, and stowed away inside as gob in empty or unused places. Sometimes a better roof is thus secured than is afforded by the natural roof of a coal-seam; as, for example, where a seam is immediately covered by a fissile slate, or by shaly or lenticular sandstone, subject to falls of scales under the combined action of weathering and gravity. This is the case with the Pittsburgh seam of the Connellsville region. The roof of this 8-foot seam is here sustained by twelve to eighteen inches of good coal left in the gangways and headings, and sometimes even in rooms. A top bench, while sometimes affording a better roof to a mine than the natural cover of a coal-seam, is—in the case of thinner seams than the Pittsburgh—usually left only on account of objectionable quality. So also with an unbroken bottom bench. This is left only when of defective quality, or when separated from the workable portion of a seam, by a persistent parting of slate or fire-clay. It is often found expedient to sacrifice an upper or lower bench of good coal, rather than separate it in mining from a parting slate even though of trifling thickness. As a rule rather than the exception, however, top and bottom benches of coal-seams contain more impurities in the form of bony coal, diffused slates and pyrite, than their interior portions. Under such circumstances a gradation of quality may sometimes be observed from a middle bench toward the exterior of a seam.

To the occurrence of partings of slates or fire-clay within the sectional or superficial compass of a coal seam, there is no limitation. Nor can any general rule governing the position of such intercalations be expected from the circumstances under which they were deposited alternately with the coal. These, in a word, comprise the intrusion of extraneous sediments, and, corresponding to their extent, an interruption in the continuity of the conditions under which the bituminous matter of the coal accumulated. The same kind of interruption, far greater in degree, is evinced by the sediments separating the several seams of the whole series of coal-measures. Sedimentary intercalations in a coal-seam are persistent or not over a wide range of area; they are few or many, or they are relatively thick or thin, according to the localization, sequence, duration and violence of the perturbations of nature which broke the continuity

of the deposition of the coal itself. The lesser extraneous sediments of coal-seams measure the effects of a shower, a wind or a flood. Inequalities of such effects are the measure of inequalities of the surface of deposition. Hence the lenticular form of such sediments within a range, wide or narrow—corresponding to the original distribution and horizontal extent of slightly depressed areas. The greater exhibitions of the same phenomena, like the splitting or division of a coal-seam by a thick stratum of shale or fire-clay, are effects of similar causes on a larger scale, or more protracted in point of time. Inequalities of the bottom of a coal-seam distinct from intrusions of intercalated sediments, of the nature of so-called "horse-backs," correspond to the inequalities of the original surface or floor of deposition. Illustrations of all such inequalities here instanced, are afforded by almost every coal-seam at intervals within the range of any wide development.

The following examples of good mining practice will serve to illustrate the preceding remarks.

In the Steam-coal region of Clearfield County, the Freeport Lower coal-bed (D) has a gross thickness of 5 to 6 feet. A top-bench of 5 to 9 inches of bony or slaty coal, developed in most of the mines of this region, is left on the roof, or else ripped subsequent to the extraction of the coal in order to prevent casualties.*

In some parts of the district this bed (4 to 4½ feet gross) is likewise mined, free from an objectionable top-bench, ranging from 6 to 18 inches in thickness. It is from these beds and under these circumstances that the superior product of this region is mined.

The Glen White Coal & Lumber Company's mine in bed B, near Kittanning Point, presents the seam as a double one, with 6 inches of bony coal on the roof, and a middle parting of 12 to 15 inches. The upper bench of 31 inches affords an excellent steam coal, while the lower bench of 27 to 36 inches is worthless from excess of impurities. The upper bench only is mined for coke making, free from the top bony coal. The same remark applies to Dr. Baker's mine in the same region, where nearly the same section is observed and a similar practice followed.

The same bed (B) is mined farther south in the Bennington coal

* The notation and nomenclature of coal-seams here used are the same as in the later Reports of the Second Geological Survey of Pennsylvania, which are likewise followed as to identification of coal seams.

Dr. H. M. Chance kindly informs me in advance of Report H_7, that the Houtzdale and the Moshannon coal in Clearfield County on the Moshannon is now referred by the Survey to the horizon of the Freeport Lower seam D.

field of Blair County, by the Cambria Iron Company (Blair Iron & Coal Company) for coking purposes, and by Dennison, Porter & Co. for market. Here the middle parting is of variable thickness, and the lower bench insignificant or sometimes entirely absent, its development being at the expense of the bottom bench as usual with such massive partings. When over 6 inches in thickness it is not removed, as the cost of stowing it away and the liability of its mixing with the coal, render the mining of the lower bench unprofitable. Under the more favorable circumstances, this is mined by Dennison, Porter & Co., and also occasionally by the Blair Iron & Coal Company. The upper bench of 2½ feet is mined by all the companies, free of its bony top of 6 inches. Space for roads and headings is cut out of the lower bench or bottom slates.

At Lloydsville, Clearfield County, the same seam (B = 6 to 6½ feet) is divided into three benches, its typical structure in this region. The two upper, aggregating 5 feet, are mined for market by the Bell's Gap Railroad Company, free of the top bony coal as well as of the bottom coal, the latter being ripped for gangway.

Bed B is mined at Johnstown by the Cambria Iron Company, and by the Manufacturing Company, free of its top bony coal, and of bottom slaty coal, the upper bench presenting a face of 3½ feet, the bottom coal being taken up only in gangways and headings.

The Upper Freeport or Lemon bed (E) was formerly mined by Dennison, Porter & Co., near Bennington, where it is now mined by the Kittanning Coal Company. In Cambria County it is mined at Lilly Station by Dysart & Co., at Johnstown by the Cambria Iron Company (Coshun and Conemaugh mines), and at Gallitzin by the Glen White Coal & Lumber Company, under varying conditions of thickness and of distribution of partings, but uniformly free of the top bony coal when developed, the fire-clay bottom being raised when its space is required for gangway and headings.

The Kittanning Upper coal (C′) at Johnstown (Rolling Mill mine) presents 3½ feet of coal, and is mined free of 1½ feet of top bony coal which is broken only in main ways.

The Berlin coal-seam is mined at Berlin, Somerset County, by the Standard Coal Company, free of a top bench of coal, 3 to 8 inches, a 5-inch parting separating it from the workable bench of 38 to 44 inches.

The Kelly seam of the Broad Top coal-field, 5 to 5½ feet in thickness, is mined by the Kemble Coal & Iron Company and by the Everett Iron Company for coking, and generally throughout

the region for market, free of a bottom bench of 12 to 20 inches of sulphurous and otherwise somewhat impure coal. This is raised in gangways and headings. The Barnet seam of the same region occurs under similar conditions, and is mined in the same way.

In the Pittsburgh bed of the Salisbury coal-field the parting between the main and bottom benches is left as floor in several of the mines. Professor J. J. Stevenson's tabular exhibit of the relative distribution of the divisions of the Pittsburgh seam in Fayette and Westmoreland counties, suggests in several of the sections given the necessity of discrimination between benches for good mining practice.*

The Bloss bed of the Blossburg Coal Company, at Arnot, Tioga County, Pa., with a gross thickness of some 4½ feet, is mined clear of a bottom "bearing-in" bench of coal, eight inches in thickness, separated in places from the main lowest workable or third bench by a parting slate of variable thickness. (2d Geol. Survey of Penn., Report G, 180.)

The Coalton or Ashland seam (VII.) of the Hanging Rock district of Kentucky, is mined throughout the district free of a top bench of sulphurous coal, ranging from 6 to 20 inches in thickness, and of the shaly parting, separating it from the workable benches, the aggregate thickness of which varies from 3 to 4 feet. Gangways and headings are driven to the full height of the roof.

In the mines of Akron Furnace, of the Hocking Valley district of Ohio, in the Straitsville or Nelsonville seam (VI.),† the upper or fourth bench with the parting of bituminous shale, is left for the roof. (Rep. Geol. Survey of Ohio, III., 839.)

It would be easy to add to the number of examples of bituminous coal mines operated on a large scale, in which upper or lower benches remain unbroken whenever of such inferior quality as to contaminate the rest of the coal if broken along with it. The practice applies equally to top and bottom benches excessively bony, slaty or sulphurous, and to benches similarly situated of merchantable coal too thin to pay for the removal and stowage of parting slates, separating them from interior workable benches. The kind of roof afforded by an unbroken upper bench is of course in each case an important consideration. The expediency of leaving it as a substitute for an inferior roof, where otherwise it would not be rejected, is not pertinent to the present subject.

Discrimination against the quality of top and bottom benches is

* Geol. Survey of Pa., Report KK—56-59.

† Upper Freeport seam (E) of Pennsylvania section.

greatly facilitated by the circumstance that an excess of ash manifests itself to the eye through an excess of slate or bony coal, while an undue proportion of sulphur makes itself known by a generous distribution of visible pyrite. These two impurities commonly go together with such fidelity that where one is found the other is rarely far off. Such discrimination does not always follow visible differences. An excess of ash and sulphur, one or both, sometimes defies detection without careful comparative analyses, perhaps frequently repeated.

While benches equally impure may occur within the body of a coal seam, it is rather by way of exception that the benches richest in bony coal, bituminous slates and pyrite, in intimate admixture with pure coal, are not the upper and lower members of a seam. Parting slates, shales and fire-clay are commonly so distinguished from coal as to be readily separated from it in the process of mining and preparation for market. But no equally ready means are available for the rejection of interior benches, however objectionable, in beds of any size, as in the case of top and bottom impure benches in seams of such thickness as to be workable after reduced in size by the rejection of exterior members.

Coal seams, whether free or not from distinctly slaty or sulphurous courses, are commonly divided into benches of various thickness and of various physical properties, involving differences in chemical relations of its several ingredients. In some coal-fields these inequalities are more strongly marked than in others.*

The methods adopted by the several recent state geological surveys in the study of bituminous coal-seams, vary widely in respect to the degree of attention given to such features as I have briefly

* The importance of considerations of the kind above brought forward, has come home to me of late in experience of my own. Having been called upon to sample the undeveloped Kittanning and Freeport groups of coals in Somerset County, in conjunction with one of our best field geologists uncommonly familiar with the coal-measures of Pennsylvania, we were surprised and disappointed with the results of analyses of the samples. The samples were taken in the usual manner. They did not, however, bear out the favorable impressions of the qualities of the several seams, as derived from their appearence in what I have termed above rustic coal-banks. I subjoin, by way of illustration, the preliminary analyses thus described, and also analyses from a second sampling by myself, in which I followed the course here recommended for such cases.

The coals referred to are from the hydrographical basin of the Quemahoning, within the Johnstown sub-basin of the First great Allegheny coal basin, in Somerset County, Pa. The first series of analyses is by Mr. Andrew S. McCreath, and the second by Dr. Thomas M. Drown.

noticed above. The surveys of Ohio and Kentucky are rich in examples of analyses of coals differentially sampled, according to a system of nice discrimination between benches of different physical characters. The system followed by these surveys is none the less commendable that the coals of which they treat often exhibit differences between their several benches, individually considered, more pronounced in character than are commonly exhibited by members of the Allegheny series of coal-seams.

The extensive series of proximate analyses of the coals of the Allegheny coal-field, issued from the laboratory of the Second Geological Survey of Pennsylvania, includes a goodly number that well exhibit its great variety of bituminous coals. I refer to analyses preceded by anatomical analysis of coal-seams, involving a discrimination between varying parts of an individual seam and a minute definition and description of the samples. The several types of coal afforded by this coal-field as a whole, and by its minor basins, are represented by analyses, the significance and value of which are not impaired by any lack of attention on the part of the field observer to the physical differences which it is the object of the present paper to emphasize. This important part of the work of the survey has been especially well done in such divisions of the great coal-field of the state as have been developed by mines and railroads, facilitated of course not only by the ample presentation of coal-seams in developed mines, but also by the practice individual to mines which rarely errs in discrimination, where essential differences occur, between the practical and comparative values of coal-seams and of their subordinate parts. In undeveloped districts of the state un-

	AVERAGE OF WHOLE SEAM.			DIFFERENTIAL SAMPLING OF SAME.				
	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Moisture, .	1.016	1.256	1.892	1.60	1.27	1.21	1.28	1.88
Fixed carbon,	68.630	69.175	65 897	74.85	77.77	75.82	74.14	72.90
Volatile matter,	17.004	17.364	18.513	14.25	14.33	15.85	15.05	16.41
Sulphur, .	3 264	2.125	3.078	1.59	0.66	0.95	1.69	0.98
Ash, . .	10.086	10.080	10.620	9.30	6.63	7.12	9.53	8.81

I. Bed C′ Pile's bank.
II. Bed E Lape's bank.
III. Bed B Hoffman's bank.
IV. Bed C′ Pile's bank. Sample exclusive of road bench (8″) and gangway bench (5″) net coal 3′7″.
V. Bed C′ Lohr's bank, sample exclusive of road bench, net coal, 3′10.
VI. Bed E Sipe's bank, sample exclusive of road bench, 9″, net coal 3′.
VII. Bed E Lape's bank, sample exclusive of road bench, 1 foot, net coal 3′.
VIII. Bed B Hoffman's bank, sample exclusive of road bench, 6″, net coal 31″.

provided with railroad facilities, so essential to the development of coal on an industrial scale, and where examples of good mining practice are not to be found, the work of the survey in the particular above referred to, has not proved equal to its best. Nor, perhaps, is it reasonable to expect that the best work be practicable without the best facilities for observation, the same as when these are not wanting. Yet the most useful part of the mission of a public survey is to lead rather than to follow. Uncalled for as may seem a close study of a coal-seam, as exhibited in the rude coal bank of a farmer, from which only a few hundred bushels are dug every winter for the kitchen fire, and which, in the geologist's time of summer, is too apt to be "fallen shut" (zugefallen), it is obvious that every considerable coal industry must have advanced from some such tender and sensitive state,—I use the term advisedly—for the geological surveyor is a mighty personage, with power to make or mar, to bring railroads or to turn them away.

Difficult as it is to recognize in the immediate rural environment industrial possibilities of the future, and great as may the effort be to the mind trained to the disuse of the imagination, yet the geological surveyor cannot be upheld in admitting into the quality of his work gradations according to the importance of immediate interests, or to the range of local intelligence by which it is at first gauged. Under the depressing circumstances that a rustic coal bank is generally inspected, like a low and crooked drift littered with ominous "falls" from a still shaky roof; its props few, if props there be, and far between; its breasts of coal perhaps weathered and hoary with the efflorescence of time, the inspector is only too glad to emerge into daylight with such samples as could be scaled from a smooth heading, and to take the chances, whatever they be, between coal, slate and sulphur. The chance is small that such sampling does quite justice to the seam, and smaller still that the analysis which follows, fairly represents its quality as "run of mine." No effort having been made to discriminate between members which in good mining practice would remain unbroken, the more reasonable probability is that a single sample represent the coal *below* the actual technical grade it would have if skilfully mined for market. In such cases, perhaps, prepossessions are allowed finally to govern, for instances not a few may be found, where the reporting geologist assumes or conjectures, after all is done, and the analysis takes its place in his report, that it is above the average if unexpectedly favorable, or below an average if less favorable than surmised. The

prestige of a state geological report is great, and its authority seldom questioned. The *modus operandi* of sampling is seldom called in question, and is seldom explained except in good examples of differential or fractional sampling. In such cases the presentation of two or more analyses of samples from a single seam forces their different explanation by separate legends. Similar explanatory notes, if not equally compulsory, are scarcely less important in the case of single sampling, if any significance is to be given to the analysis. Whether it represent "run of mine" as prepared for market, or the whole or part of a specific sectional measurement of a coal seam, or whether it include dividing slates, or roof and bottom benches of impure coal, are questions vital to the practical interpretation of every analysis. The benefit of the doubt where any such questions arise, cannot be safely given to the coal. It bears, for the time being, whatever character it derives from even a single analysis, if there be no more than one, especially if the analysis be against it. If, on the other hand, the analysis be in its favor, any error in the estimation of its practical value is the sooner discovered the greater appear the inducement to give it close attention. So keen is the competition between coal districts, and so redundant for the present time the resources of our great bituminous coal-fields, that mere impressions against a coal are often sufficient to condemn it. Inadequate sampling or unskilful mining, in a single instance perhaps, has often proved sufficient to keep back the industrial development of valuable resources, to the prejudice not only of local interests but also of interests of a wider scope. Persons among the more sagacious and experienced, are quickly influenced by adverse analyses, without a thought given to the widely varying conditions under which samples for analysis are commonly furnished.

The disappointment to a close inquirer from failure in significance of an analysis for want of particular identification of the sample, bears no reflection upon the work of the laboratory, provided the chemist report along with the analysis the local description accompanying the sample from the field. But it is wasted labor on his own, as well as the analyst's, part to have his search rewarded, only to discover it to be void of significance or value from lack of specification of the parts of the seam represented by the sample analyzed. When one sample and one analysis has to do duty for more than one,—all the more care should be taken to insure and define the exact identity or significance of the sample. No scientific importance attaches to the analysis of a single hand specimen taken from the stock-pile

of a coal mine, regardless perhaps of the length of time it has been exposed to weathering oxidation, or of a sample broken at random from the breast of a coal seam, or worse still from an outcrop inured to weathering for immemorial time. It does not alter the case, that such an analysis may pass current among persons on whom rests no responsibility for accuracy in such matters, or concern for errors not falling upon themselves.

If insufficient or indiscriminate sampling of a coal-seam thus deprives an analysis not only of scientific importance but of technical or practical value, although often received as conclusive in the absence of better work be the consequences what they may; what degree of importance can be claimed for purely conjectural inferences drawn from analyses of coals as to the particular source, the character or the significance of the samples—and this on the part of the reporting officer himself who furnished the samples? Or what may be the measure of value for an analysis on such uncertain ground as to what it represents that it may be summarily negatived by prepossessions from the field, and thus proved to stand for nothing in particular?

In such inverse order, the identity or significance of the sample is argued from the analysis, as if the acceptance of a sample should leave open any room for question as to what it be a sample of—whether of one portion of the seam or another, of the whole or a part, or whether it include or not certain members. Yet numerous instances can be cited where speculation pure and simple, or inductive reasoning, is thus called into requisition to dispose of questions of which these are general examples, and which, after the reporting geologist has taken leave of his field, and after returns from the laboratory are in his hand, it is altogether too late to propound to himself. Such analyses, it may be contended, whatever may be the excellence of their execution, are less satisfactory for any serious purpose than none at all. The review and correction at the hands of private persons of hasty work on the part of public authorities, are beset with other difficulties besides those of the problem itself. No imputation of partiality or prejudice rests upon the official. From the mere nature of the case the work of the private reviewer, however, so far as it is amendatory, partakes of the character of special pleading. Extra work, perhaps often repeated, and a wider range of work than otherwise, are therefore entailed upon him if he undertake to demonstrate the qualifying conditions under which a coal-bed is really better than it may have once been pronounced. Despite an analysis suf-

ficiently unfavorable to condemn *prima facie* any coal when indiscriminately sampled, or when impurities have been included in the sample which never would be included in the mine product, a coal may actually prove to be unexceptionable when sampled according to its requisite technical treatment. In any of the reputable instances above cited where complex seams are mined free from objectionable members, it is certain that samples from mined and rejected members alike, would result in analyses fatal to the coal in its very best markets. Is it too much to impose on a geological survey that the study of a coal-seam in its topographical and stratigraphical relations, be extended to its economic conditions from an engineering or practical point of view? That this is incumbent on a survey which freely passes judgment *ex cathedra* on the practical qualities and conditions of coal-seams, will not be questioned. Yet reference to the reports of some of our recent state geological surveys, will convince the inquirer that the engineering skill applied in the field is not always a sufficient warrant for the degree of confidence with which final judgment is offered in such matters. This is more generally the case in undeveloped districts where good practice has not led the way to a critical discrimination between divisions of a coal-seam, or between different members of local sections of the coal-measures. Under such circumstances an official survey owes more to industrial interests than in undeveloped districts it returns in kind. Yet an official survey is presumed to guide rather than to follow, and in collating known facts in a developed field, to apply them *a priori* in an undeveloped field. In its relations to industry an economic survey is presumed to exercise foresight as well as skill, and, whatever be the measure of its actual performance, is believed to be wise in both.

Important and always welcome as aid from skilled mining must be considered, the lack of it does not absolve an official survey from the duty of locally determining the working conditions of a coal-seam from its exhibition in rude openings, however narrow the compass of the observation, provided this qualification be specific. In the lack of mining operations on an industrial scale, the field observer is called upon to consider their practicability. Yet it is far from safe to take bad work as an exponent of good work. Of what good practice would be on an industrial scale, the makeshifts of the modest coal bank, wrought only for domestic supply, or to meet a local demand—not overnice as to the quality of the product—indicate but little. As a rule no discrimination is used against top and bottom,

slaty or sulphurous benches, all being gladly taken for coal which falls under the pick. Good farmers make bad miners. This is no less the rule than conversely it is exceptional to recognize a good farmer in a good miner.

Handicapped as an undeveloped coal area always is through the lack of good examples of practice, and of facilities for comparative observations, it behooves an official survey to make the best of what means may be found for the anatomical and analytical study of its coal-seams, and, in this branch of study at least, to be found when at an end in advance of industrial operations. To have them followed up, even though from far in the rear, and finally chronicled, is satisfactory to all. But this is only one of the minor offices of a survey. The conservatism which shrinks from the responsibility of leading, and from the danger of misleading, where industry has not gone before, is little likely to err from positive opinions in practical matters, but to hedge in such as it offers, and to stand non-committed to all where condemnation does not seem perfectly safe by the discovery of no ground for challenge. In some recent reports this disposition is altogether too apparent. Courage of opinion is specially commendable in the report of a public survey. Limited in scope, as in point of time it must needs be as long as the survey itself is an establishment but for a short period, nobody goes to it for final judgments. Its character should square with the fact that it is but an effort in the way of systematic inquiry, which it is its best office to further, and by its opinions freely offered to stimulate, rather than to finally dispose of. Thus, as it seems to me, its procedure, following a true theory of the nature and limitations of its field of work, should be argumentative rather than judicial.

The short life of our surveys imposes undue haste in their execution. Their maintenance and continuance are too often at the will of the legislature, from the first, perhaps, indifferently expressed by a vote portentously close. At the peril of even its short life the voting power calls for propitiation. In what manner this shall be offered is a question presenting itself differently in each case, according to the different personality of legislators and of the chief of the survey, or, haply, of an intermediary board of commissioners. The usual concession seems to be to the popular notion of what is fair. And it is considered fair that the distribution of work shall not be otherwise than even throughout all the legislative districts of the state, and that no partiality shall be discovered in favor of any one, however supremely interesting or specially important. All must be

treated alike on pain of raising a grievance, and perhaps forfeiting a majority, the very breath of life to every survey however hard to keep.

Regarding an official survey not only as a contract but as a scientific trust, it might be open to question whether it be an act of good faith, at least to science, on the part of its followers who accept and even seek the charge of one, to do so on such unequal and compromising terms as its limitation to a period and to a cost clearly inadequate to the best performance of more than a small part of what is called for by the bill which creates it, and which, with all its restrictions, the most promising candidate in the field is the person most likely to have drawn up. It might be held, in justification for such things, that if surveys did not come into good hands even in this way they might fall into bad. This cannot be denied. And, unfortunately, no high standard of work can be uncompromisingly fixed and evenly maintained until state surveys come to be constituted as a continuous service like those of the more enlightened countries of Europe. It were idle to hope that on any other basis than a permanent one, a practicable plan for their organization can be devised which shall warrant the exaction of a high class of work up to the best European examples of public surveys. Methods of work involving close attention to details in various branches of study on the part of a single division of a survey are vainly insisted upon, under the exigencies of surveying the wide expanse of a whole county within the limits of a single summer. Thus the reconnoissance takes the place of a survey—especially in undeveloped districts, and hence wide differences in the grade of work in such districts as compared with that in the better developed districts. This difference often appears out of proportion to the relative difference in available facilities for observation and study.

The same expedition cannot be used in both cases, nor in both is the requisite work of the same kind. Meagre and inconclusive as results from an undeveloped field may be, their cost in time and labor may be far greater than in the case of a richer showing from a field which industry beforehand has opened to view. Regardless of inequalities of this sort, the public is apt to gauge the performance of a survey—not literally by the pound of publication—but, what is about the same thing, by the volume of its reports.

The evil of bad sampling is far from being confined to its particular instance. Whether of coal as a product or of coal as the type of the local occurrence of a coal-seam, the analysis is usually accepted

for what it is offered, without critical retrospect as to the sample, or inquiry into the act of sampling. The uses to which it may be put are various, including scientific, technical and commercial uses. It goes into the literature of the subject, and passes current among the demonstrations of science and the arts. It enters into the careful tabulations from which mean averages are cast, comparisons made and generalizations drawn.

It is in no captious spirit that in the course of such uncomplacent remarks, I refer again to the extensive series of proximate analyses of bituminous coals published by the present geological survey of Pennsylvania. Its wide range and the high estimation to be accorded to official authority, invest this series with special importance, representing, as it does, the various types and local differences which give character to the largest and best-developed part of the great Allegheny coal-field. The uniform skill which this series exhibits on the part of the analyst, is beyond question, and the assiduity of which it is the evidence, on the part of the same officer, remarkable and even surprising if it be considered how brief is the period within which it has been accomplished. The concrete and systematic form of its summaries, as issued from the laboratory of the survey, renders it specially available for the present purpose of illustration.

Taking this series of analyses along with the several contexts in the form of descriptive reports, it does not fail to afford notable examples of good and faithful sampling of coal-seams preliminary to analysis, including differential or fractional sampling in certain cases, especially where industry had already indicated the practical differences to be observed. In such cases, the circumstances which governed the sampling are duly recorded in the texts, and the corresponding analyses defined accordingly in the special publications of the analyst along with the report of his work. Many individual instances of good practice leave little if any room for improvement. But instances of undefined analyses proceeding from indefinite sampling, as shown by the texts, are still more numerous. It is not necessary to specify these. Suffice it to remark in a general way, that they well serve to illustrate the several points to which my subject directs attention.

A climax of the evils I have referred to as arising from inadvertent or indiscriminate sampling, is witnessed when analyses, qualified by nothing better for such good company, are given place along with such as the descriptive text reflects no doubt or discredit upon.

In order to exhibit the centesimal proportion of sulphur in Pennsylvania bituminous coals, I once* took occasion to cite some of the mean averages deduced from one of its own tables of analyses by the present geological survey of that state.†

Upon a close examination of this table, I now perceive that all deductions from it as a whole are vitiated by factors which render it useless for purposes of generalization. Notwithstanding all the facilities that ever offered must have been enjoyed by the tabulator for distinguishing between the analyses according to what they represent, the mean averages are from a list which includes, along with examples of merchantable coal, not only examples of condemned coal from abandoned workings, but also foreign substances such as unmined roof and bottom benches in their relation to workable coal are really to be considered. Who can sift from his averages such destroying elements if not the tabulator himself? Even after recourse to the texts and the recognition of the grosser intrusions, still a number of equivocal examples remain. Hence the troublesome elimination of certain factors and the recasting of averages still leave deductions from it open to question.

In its bearing, for example, on the sulphur ratio as shown by mean averages from parts, or from the whole, of the list in question, it is found to include, along with other at least questionable company, samples from parts of coal-seams so rich in sulphur as to be without standing in a list of merchantable coals, for which indeed perhaps nothing in the text is claimed to qualify them. I refer to samples characterized by sulphur in excess,—notably from roof and bottom members of coal seams,—sufficient, if these were mined, to destroy the commercial value of their better members, when occurring in relation to the latter in any such proportion as to call for special recognition.

What is thus to be said of the sulphur ratio bears with equal force upon the ratio of ash. I have already explained that the more sulphurous parts of coal-seams are often likewise the more slaty portions, and therefore the richest in ash. Enough has been adduced to show that such parts of coal-seams, especially objectionable roof coal and bottom coal, are seldom extracted except in mine entries and gangways for the sake of giving convenient height to these thoroughfares. Few, if any, collieries are without occurrences of

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* Relations of Sulphur in Coal and Coke, by the writer. These Trans., viii., 192.

† Report M, 1875, 38.

pyritous coal in more or less concentrated forms, readily admitting of separation. When occurring bodily in the interior of seams, excessively pyritous coal is rejected sooner or later, wherever practicable, along with shaly partings, between the laminæ of which it is commonly deposited, even at the cost of sacrificing adjacent benches of good coal if necessary to insure the purity of the product. Thus quality is often at the cost of quantity. The mean average quality of a coal-seam, as such, is therefore generally a matter of minor interest. The question of paramount and vital importance is the mean average of its product as actually mined or as it should be mined, and as finally or properly prepared for market.

Loose practice in sampling coals for analysis tends to detract from the value of all the analyses of a series, however well executed all may be, and whatever be the proportion of the number of those which are free from objection on the grounds above noticed, or from questions as to what they stand for. When collected into tabular exhibits without means for discrimination, and when employed for mean averages without discrimination or qualification, it is not to be expected that in comparison with quantitative exhibits of other coals they will appear to their full advantage.

The ratio of sulphur and ash in the bituminous coals of Pennsylvania, already deduced by the present geological survey of that state from collations of analyses in gross, without discrimination as to the widely differing practical significance of the samples represented, compare either unfavorably with similar exhibits properly prepared to show these ratios, or at least less favorably than if these ratios were reckoned, not as they vary in different areas of a single seam but as possessed by coals properly mined and prepared for use.

Averages from parts of the same exhibits display the coals of certain sections of the state below what is discovered to be their grade if objectionable factors be eliminated. These factors are not always specifically characterized, nor evenly distributed according to the grouping of localities. Even when characterized as samples from unworkable seams or from unworked parts of seams, their analyses enter nevertheless into the averages found in the text, and from these averages general deductions are drawn and comparisons made. Comparisons of divisional averages are therefore made on unequal grounds, to the prejudice of certain sections of the state, and to the exaltation of other sections. Coals of a certain section, exhibited below their true commercial character, may seem to be excelled by types known to be inferior from another section of the state—perhaps a

rival in its coal industry—from other states, or from other parts of the world. Such promiscuous exhibits are almost equally unhappy even when not already geographically grouped or used for purposes of generalization, as they are always liable to be rearranged, and so used in whole or in part. The grouping of coals by counties, as in Pennsylvania, is a far less practical arrangement for purposes of comparison than a grouping by basins; or, still better, a grouping by coal seams, subordinate perhaps to basins. An omnium gatherum of analyses of all the miscellaneous material sent in from the field can prove no title to be considered an exhibit of coals of the state, however grouped. As an exhibit, as a whole or as dissected into minor parts, failure of averages from it is on the side adverse to the better qualitative conditions of the examples. That the bituminous coals of Pennsylvania are of so supremely high a quality as not to show up only indifferently well when averaged along with extraneous or top and bottom slates and bony coal, or with earthy or sulphurous by-products, as well as with local occurrences of condemned coal, is indeed too much to expect.

The following illustrations in brief, from tabulations of the Second Geological Survey of Pennsylvania, will, it seems to me, bear out the preceding remarks.

By way of exhibiting the quantitative relations of iron and sulphur in representative coals, a series of excellent analyses is offered, consisting of 28 examples of coals from different parts of the state (Report M, p. 26). The ratios of sulphur incidental to this investigation prove at a glance, in at least one-third of the whole number of examples, in excess of what could be tolerated in merchantable coal. Without stopping to inquire whether on such a plan this exhibit does not defeat its own end, it will be conceded that the selection of highly sulphurous material, of which a number of examples are proportionally rich in ash, outside the pale of merchantable coal, vitiates all general deductions from such an exhibit as a whole for technical purposes. Generalizations on the relations of sulphur from percentages of 7.611 and 8.350 in the case of the outcrop of an undetermined coal-bed in an undeveloped part of the Reynoldsville gas-coal basin, so-called, are at least of doubtful utility (Report M, 31–32). Another similar example, with 3.378 per cent. of sulphur, is from the lower 14-inch bench of the Lower Freeport seam, in the mine of the Decatur Coal Company, of Clearfield County (Report H, p. 48). This sulphurous bench is separated from the main bench of 34 inches by 2 inches of parting slate. Whatever

be the practice at this mine, it is clear that such a tenor of sulphur is enough to condemn it, especially if the upper bench be so rich in sulphur (1.373) as to suffer from further sulphurous contamination.

The same volume (Report M, p. 38) presents another tabulation of 85 analyses, useful enough in themselves, but so arranged as to nullify whatever quantitative deductions be drawn from the tabulation as a whole, or from its systematic parts as divided by counties.

The several percentage ratios of essential parts of coals are necessarily reduced in all averages which include examples of condemned coal or of unmined benches, in proportion to the excess of the latter in sulphur and ash.

The ratio of sulphur in Clearfield County coals, 34 in number, as deduced from this exhibit, is as high as 1.36 per cent. (Report M, p. 30). This is about double the proportion characteristic of the famous steam coal afforded by the Freeport Lower seam on the Moshannon, and which gives character to the extensive coal industry of the county. The average of ash, as determined from the same examples (5.30 per cent.) (Report M, p. 29), is likewise above the local standard of these two beds as mined for market. These ratios are thus unduly large, and the ratios of essential parts proportionally reduced below standard by including in the averages such examples as one from the rejected lower member of an undetermined coal-bed near Clearfield, and which the descriptive text condemns on the evidence of the analysis showing sulphur 4.232 per cent. and ash 13.180 per cent. (Report H, 91).

The percentage of ash averaged from analyses of five coals from Centre County, and representing the Snow-shoe coal region, is given as 5.38 (Report M, 29). This is swollen by a single factor of 10.450, which represents the ash of a sample of the Kittanning Lower bed (B), and which as an average the descriptive text assumes to be "entirely too high." It may be remarked in passing that reference to the section of the seam in this instance, will suggest a fine example for differential sampling (Report H, 71). The mean average of ash in the four unobjectionable samples, is 4.120 per cent. The difference, though slight, goes to the credit of the combustible parts of the coals.

The coals of Jefferson County, including those of the Reynoldsville gas-coal basin so called, suffer from the intrusion of examples from unworked and so-specified benches of the Lower Freeport bed, in the Diamond Colliery (Report H, 153), carrying sulphur in the

percentage proportions of 3.101 and 2.284, and ash as high as 19.170 and 8.400 respectively. The text in this instance exhibits a fine model of differential sampling. A sample from the outcrop of an undetermined bed of the Lower Productive series, just across the line of Clearfield County and known as Brown's bank, swells the average of sulphur and ash by percentages of 3.885 and 18.950 respectively. The so-called Creek coal of Reynoldsville, an undetermined member of the same series, with 3.593 per cent. of sulphur and 11.700 of ash; and the Galusha coal from the outcrop of an undetermined bed in the northeastern continuation of the Reynoldsville basin, with 7.140 per cent. of sulphur, contribute inordinate ratios of these substances to the account of the coals of Jefferson County. Thus deduced from 37 examples the mean averages of sulphur and ash are given as 1.518 per cent. and 5.45 per cent. respectively.

To the Armstrong County list of six coals, it must be objected that two of the number are examples of cannel coal, which is the local occurrence of the upper portion of the main bench of the Kittanning Upper seam in the Red Bank colliery at New Bethlehem. This type of coal in general, and examples like these in particular, with percentages of ash as high as 22.230 and 17.320, are out of place in an exposition of bituminous coals for purposes of general average, into which they cannot enter without confusion to all mean determinations. High ratios of ash must be borne alone by cannels in which they can be tolerated, and not suffered to bear against all the ratios of bituminous coals, which is the effect of averaging the two varieties together.

The coals of Armstrong County are represented by six examples of the miscellaneous products of two neighboring workings within the limited compass of an abnormal occurrence of the Lower Freeport coal in the vicinity of New Bethlehem.

The fatally high sulphur ratio of 3.30 per cent. is treated as an average of Clarion County coals (Report M, 30), although the mean of only three analyses, two being in duplicate, and the third representing an abandoned opening near the outcrop at Fairmount, of the precarious Kittanning Lower coal, with percentages of 8.427 of sulphur and 13.70 of ash.*

In a later volume (Report MM, 1879, p. 124), the study of the relations of sulphur and iron in the coals of Pennsylvania, is pursued on the same plan, to which I am constrained to object, not only on the ground that this plan unfits the general results obtained for the

* See Report VV, 105, for later analyses.

practical application which is the main purpose of such a study, but also on further grounds incidental to its main purpose. In this table 25 coals from different seams and various localities yield a mean average of sulphur as high as 2.138 per cent. An average so inordinate from so large a number of coals is to be reached, in Pennsylvania at least, only by carrying to an extreme the selection of highly sulphurous examples, which, one sees at a glance, represent anything but the merchantable coals of the state, the better resources of the localities cited, or the better developments of the coal-seams instanced.

Essential or fuel ratios, determined from a collation of analyses, including objectionable examples like those above instanced, manifestly share all errors of the class referred to.

The extent to which fuel ratios are sometimes estimated from analyses taken in good faith without close inquiry as to what they represent, and treated as gradations of a continuous series of coals of progressive types, may be witnessed in Dr. Persifor Frazer's deductions from the same series of analyses to which exception has here been taken without reflection on the chemical part of the work, on the ground that many of them do not represent coals at all, while others stand for coals which fail to pass for fuels (Report MM, 147).

Again, the extent to which the fuel ratios are affected to their detriment by sulphur ratios, may be inferred from Mr. McCreath's trial calculations, by way of calling attention to differences in fuel ratios when is taken into account volatile sulphur alone, which theoretically is but little more than half ($\frac{9}{16}$) the total amount of the sulphur attributable to pyrite alone,* and less than half the amount represented in many analyses. This difference, however, is appreciable only through sulphur in such excess as to debar the sample from all such general investigations of coals, advisedly so considered.† A still greater difference in fuel ratio will be found to arise from an undue proportion of ash, and when this as well as sulphur is in excess in the same example, as often happens, it is clear that the resulting fuel ratio must widely diverge from that of the type with which such an example has local affiliation. Although sulphurous and earthy constituents, quantitatively considered, are simply inci-

* See Relations of Sulphur in Coal and Coke, by the writer. These Trans., viii., 195.

† If, as in the volumes referred to, the proportion of coke be *estimated* rather than *determined*, an appreciable error arises from failure to allow for volatile sulphur.

dental in their relations to fuel ratios, they, nevertheless, may be so considerable in proportion to the whole, as to distort the fuel ratio of a coal quite outside the range of what belongs to its type. Enough has been said to indicate the frequency with which such disturbing examples of coal and coaly material have been suffered to stand as premises for recent deductions from analytical tables of Pennsylvania coals.

Unless it can be shown that the calorific constituents of earthy intercalations of coal-seams exist in the same ratio as in the coal itself, there can be no warrant, in the classification of coals by fuel ratios from proximate analyses, for disregarding an excess of ash attributable to such intercalations not entering as impurities into the coal as produced for use.

Without stopping to inquire what are the true relations of sulphur to the fuel ratio as expressed in terms of a proximate analysis, and instead of recognizing any necessity for recasting Dr. Frazer's ratios, so as to allow for volatile sulphur when in notable proportion, as proposed by Mr. McCreath (Report MM, 157), it seems to me that it would be better to incontinently cast out all examples exceeding the practical limits of both sulphur and ash, as wholly unsuited to the purpose of such generalizations, and as fatally subversive of anything like a continuous classification of fuel coals wherever admitted. It is the sulphur and ash ratios of the bituminous coals of Pennsylvania that stand in foremost need of being recast in favor of strictly fuel coals, to the exclusion of any without title to be so regarded. A correct scheme of fuel ratios of the coals of the state can only follow a revision of present official exhibits of their ratios of sulphur and ash.

For the purpose of a differential sampling of a bituminous coal-seam something like the following plan will ordinarily answer. The prefatory remark should be made, that every case should be considered by itself before being subordinated to any general rule.

The selection of the section should be in observance of its character as locally representative of the seam. If this be not exposed by openings or outcrops sufficient in size or number to indicate what features are persistent, the question of the representation of the seam by the section chosen for sampling must be held in abeyance. From the nature of the circumstances under which coal-seams are sampled for analysis, this must remain an open question for the time being. To dismiss it with an assumption leaves it open as before.

No question should remain as to the representation of the given

section by the sample in the specific way it be undertaken that the sample shall represent it: that is, whether as a whole or in part, whether with or without specific benches or partings, whether with or without allowance for pyritous intrusions which would be rejected in mining.

The selection of the section made, and the significance of the sampling determined, the next proceeding is to break down the sample so that it shall equally represent all parts of the section under process of sampling. This is a piece of nice work in which the personal equation involves good latitude for error. Up to this point no maxims can supersede the use of wise discretion, guided by a keen eyesight—not, however, to be implicitly trusted under-ground until well composed to the sudden change from daylight.

For want of some mechanical device for equally channeling a breast of coal under process of sampling, the sampler must trust to the skilful use of the pick in his own hand. The miner's coal-pick in miniature is probably the handiest implement for the purpose. This should be well pointed. Now it is not so simple and easy a matter as it may seem, to satisfy oneself as to the equality of a sectional cutting of a breast of coal. Coals of unlike physical properties fall unequally under the channeling of the pick. A friable columnar coal cuts readily, and falls perhaps in larger lumps than intended from beyond the line of grooving. Lamellar coal, on the other hand, breaks less freely and only under heavier blows, and in a state perhaps so pulverulent that it may become difficult to be satisfied as to its proper proportional quantity. Splints likewise refuse to be broken in lumps, and slaty and bony coals still more obstinately without force and perhaps a heavier instrument. Dividing slates and clay break according to their consistency, whether more or less fissile or more or less indurated. Exceptions to the structural tendencies here noted are not uncommon. The comparative tenacity and resistance opposed to the pick by coals of different physical structure may be modified by still further differences in bedding and cleavage.

The sample taken and bagged, a systematic plan is concluded nothing short of the record of the act. Nor is the sampling properly recorded if not recorded on the spot, nor sufficiently if not fully described in detail, or if anything be left to be supplemented by the memory. No sample is worthy of analysis on which oath cannot be taken as to exactly what it is a sample of. For speculation as to the sample itself in its relations to the section sampled, no room can

be allowed. An analysis has no value except through the significance of the sample. Significance must be given to the analysis by the sample—not to the sample by the analysis. A good sampling can be known only by its record. It may as well be bad as to be imperfectly described, so as to leave room for speculations after analysis.

It would be well always to consider the first local sampling of a coal-bed as tentative, and as preliminary to further investigation. One sampling is not enough to test the qualitative conditions of any considerable area of a coal-bed, and as a matter of course is by no means even a final test of the section sampled. Every analysis preceded by critical and tentative sampling, offers new light for every successive test. The first general sampling of the whole section of a coal-bed often suggests the necessity for sampling it differentially. This is especially the case where objectionable benches are not readily recognized by the eye.

I. The "run of mine" can approximately be determined in advance of actual mining in the case of a coal-bed presenting coal of different qualities in benches of various thickness, if these have been differentially sampled and analyzed, namely, by deducing from the several analyses new proportions in ratios of the sectional measurement of the given workable benches.

II. Or, similar results may be obtained directly in the laboratory, namely, by taking a sample, dried at the usual temperature, that shall contain by weight samples of the given workable benches in the proportions of their sectional measurements.

The slight error arising from differences in specific gravity with the same type of coal from separate benches in one seam will be inappreciable, and far less than is likely to be the error of the personal equation in sampling directly from a stock-pile for run of mine.

The first proposition may be illustrated by a single example of differential sampling of the Bloss Coal Bed of the Blossburg Coal Company, by Mr. Franklin Platt, at Arnot, in the Blossburg Coal Basin, taken in connection with its section and with Mr. McCreath's analyses of the separate benches. (Report G, Second Geological Survey of Pennsylvania, p. 180.)

These analyses are here presented in tabular form, together with my own deduction therefrom in a fourth column, by way of showing the centesimal composition of run-of-mine.

AVERAGE SECTION OF THE BLOSS COAL-BED, OF THE BLOSSBURG COAL COMPANY, ARNOT, TIOGA CO., PA.*

	Roof slate,	——
I.	Coal, top bench, average,	1′ 0″
	Slate,	0′ 1″
II.	Coal, middle bench, average,	0′ 8″
	Bone coal, rejected,	0′ 2″
III.	Coal, bottom bench, average,	1′ 8″
	Slate,†	0′ 4″
	Coal, "bearing in" bench, rejected,	0′ 8″
	Fire-clay floor,	——
		4′ 7″

ANALYSES OF BENCHES I, II, AND III. BY ANDREW S. McCREATH.‡

	I.	II.	III.
Water,	1.190	0 940	1.110
Volatile matter,	20 755	20.640	18 790
Fixed carbon,	71.697	64.306	63.428
Sulphur,	1.023	0.914	0.602
Ash,	5.335	13 200	16.070
	100.000	100.000	100 000

RUN-OF-MINE FROM MEAN AVERAGE OF ABOVE ANALYSES IN PROPORTION TO THE GIVEN THICKNESSES OF THE WORKABLE BENCHES.

Water,	1.1000
Volatile matter,	19.7495
Fixed carbon,	66 0843
Sulphur,	0 7907
Ash,	12 2755
	100.0000§

* Report G, p. 180.

† This division is obscurely given in the text. I therefore give it as 4″, which is stated by Mr. H. J. Landrus, manager, to be its fair average from a maximum of 12″ in places where first opened to nothing in the larger part of the mine.

‡ Report G, p. 181.

§ A similar mode of differential sampling, and of sectional average of analyses, may be applied to other comparatively homogeneous minerals like iron ores, *in situ*, under certain circumstances. For example, a nice question recently before the courts of Pennsylvania was as to the average quality, incidental to the question of quantity, of the Clinton or fossil ores of a certain part of their range in the eastern flank of Tussey Mt., in Bedford County. The experts on both sides of the question (for there seem to be two sides to every question of fact as well as of opinion in such matters under adjudication) were nearer in accord as to sectional measurements of the two nearly homogeneous divisions of the ore-belt, as presented in specific cuttings, than they were upon the practical question of mean average quality as exhibited by these cuttings. No empirical plan for the solution of such a question, in cases of this limited kind, seems to be so free from objection as that here suggested.

It will now be proper to ask what shall be considered to be the maximums of sulphur and ash in merchantable coals? This question will be answered differently in every region, and even in the same region at different periods. The exigencies of every coal region, its resources and its trade conditions at any given time determine the answer to such a question. Governed by conditions of trade, including railroad facilities and distance of market, competition between different regions or between parts of a single region, goes quite as far toward deciding the matter as relative degrees of purity of coals, or as considerations of general and local supply and demand. Personal considerations are often not without share in the matter. Hence exceptions to the general proposition that an indifferent quality of coal may retain its hold on its market until met on equal terms with coal of a better quality. For the poorer quality is not always supplanted by the better. A large class of consumers of coal are not so far above caprice or prejudice that the standing of a coal in the market is wholly upon its merit. Besides, the latitude between the cost of certain coals in a given market is often wider than the range of difference in quality. Fuels like ores do not take their standing in the market from constituent units. This is due to the lack of expeditious and popular means of analysis, in cost and labor not out of keeping with the value of results applied on a moderate scale. Until their comparative values are made up from both sides of an account between essential and non-essential units, coals will continue to present a remarkable example of a great staple whose values are arbitrary.

In place of quantitative limits, certain limits of practical effect are observed by almost every large consumer. Yet again these limits in practice will be found to vary, as vary local considerations of comparative cost and of supply and demand. Thus it is clearly impracticable to draw hard and fast lines which the ratios of sulphur and ash shall not pass without forfeiting the right of a coal to commercial standing. Nor should the recognition of the practical standing of coals be on such narrow grounds as to include only such as find a way to market, to the exclusion of that large part of the coal production of the United States to be distinguished as "native" raw material for industrial works. It is the producer of coal rather than the consumer who knows from experience what are the limits which cannot be exceeded, and how far it is prudent to approach even these. To his standards therefore is the proposed question at present to be referred. These will be found to vary according to

the varying degree of toleration by industry and trade, as determined by their necessities and by economical considerations. Indefinite as the answer must be, it suffices nevertheless for the purpose of the present inquiry in the interest of coals strictly regarded as fuels. The title of a questionable coal to rank among fuels is indefeasible if the coal be used on a considerable scale. But the burden of proof rests with the coal. Local and even popular use for domestic supply and sugar-boiling is however not to be considered general or technical use in the sense here considered.

The coals of the Middle States, invaluable to the industrial resources and prosperity of these states in their own field, clear of competition with coals of a superior type, would on equal terms with those of Virginia and Pennsylvania, for example, be handicapped by their high ratios of constant moisture. So too with the coals of Pennsylvania itself. Barclay and Blossburg coals enjoy a larger field of trade than falls to the lot of better coals in other markets open to competition, and with still further odds in their favor. Broad Top coal which replaced the production of the Cumberland mines when interrupted by the War of the Rebellion, lost its vantage-ground through careless mining, and was easily supplanted by Cumberland coal on its return to market. Coal which proves highly acceptable for the coal trade supplied by the Baltimore and Ohio Railroad from Somerset and Fayette counties would be received on a less favorable footing along the line of the Pennsylvania Railroad in competition with the coals of Clearfield County. The coals of the Conemaugh in Cambria County, which enter so largely into commanding local industries and for whose purpose they leave so little further to be desired, are scarcely fitted and have never essayed to contest a market with coals from the Moshannon, Snow-shoe and Reynoldsville districts of the adjoining county although from the same seams. While in such examples other qualitative differences weigh besides those affected by ratios of ash and sulphur, all points of objection may be considered in brief for the present purpose of illustration.

The "stocking" qualities of a coal have a good deal to do with its standing in some markets. These depend upon its frangibility, itself a condition of the divisional structure of the coal as imparted by cleavage and to a minor degree by lamination, or as a condition resulting from a high degree of purity. Sound coals poorest in ash and proportionally rich in bituminous matters, are generally the most friable. Of such a character are some of our best steam coals, like the Clearfield. Conversely, coals rich in ash are commonly

tenacious, and the more so the nearer they approach the character of a splint. Laminated coals possessing even a low degree of cleavage are rendered friable by diffused pyrite (marcasite) in the process of weathering. (See memoir by the writer On Atmospheric Oxidation or Weathering of Coal. These Transactions, viii., 1880, p. 215.)

To be more specific, a high degree of primary frangibility in freshly-mined bituminous coal may generally be accepted as an evidence of purity, when resulting from the columnar cleavage and brittleness of lustrous and highly bituminous laminæ. For these are the attributes of a bituminous coal, composed of such laminæ poor in ash, when these are not in minute alternation with cannel-like laminæ comparatively rich in ash. It is the cannel-like laminæ which impart firmness and tenacity to prismatic coals, and the more as coals of this type approach the character of splint or of cannel. Bituminous coals, free from slate, are therefore as a rule the more tenacious and blocky in about the same measure that they exceed the minimum of ash and the more friable in the measure of their purity. The rule is not affected by the fact that minute intrusions of earthy sediments, still richer in ash, often impart to freshly won coal of both classes a special tenacity, which however generally relaxes rapidly on exposure. The common association of pyrite with such earthy sediments in coals induces what may be called *secondary frangibility*, as a result of weathering: whence the poor stocking qualities of some bituminous coals. Such qualities again bear some relation to the ratio of sulphur and likewise of ash.

If specific maximums of sulphur and ash cannot be given, or the points fixed where undue proportions of these constituents become prohibitory, it may be asked what are the practical effects by which excess of these constituents shall be decided?

I have in a former paper discussed the relations of sulphur in mineral fuels with some reference to that part of this technical question. (Relations of Sulphur in Coal and Coke. These Transactions, viii., 1880, p. 181.)

In conclusion of the present remarks a few words will suffice on questionable proportions of ash in bituminous coals without reference to its qualitative relations in technical uses. The point then to be considered is simply the calorific efficiency of mineral fuel in relation not to low ratios of ash which are inevitable and all but essential, but to proportions so considerable on the one hand as to become questionable, and on the other hand so large as to be prohibitory.

Such questions practically considered, apart from the refinements of the subject, often turn on other considerations besides those strictly appertaining to the ultimate constitution and physical conditions of coal. It is probable that they are generally quite as susceptible of satisfactory solution by simple arithmetical process as by defective methods of experimental demonstration and comparison. Thus in proportion to the ash of a coal, without reference to its water and the heat of combustion absorbed thereby, it will be easy to reckon the dead weight at which such matter, regarded simply as inert, is invoiced, and on which freight and labor are paid, and perhaps commissions and interest. So too any question of water, whether hygroscopic or adventitious. In the case of western coals and those of the interior continental basin, this question sometimes becomes important. (Some such process must be employed, or at least comparisons practically instituted, to justify the extensive importation of coals from western Pennsylvania and West Virginia, for the use of blast furnaces on the Ohio, in competition with native coals of the same type rich in water, if not in sulphur and ash.) The calorific power of coals must be diminished by heat units absorbed by ash and water, and must be in some simple inverse proportion to these constituents, whatever may be the complexity of the conditions affecting their calorific constituents. So much at least can be relatively determined toward the calorific value of coals comparatively considered.

Actual trial and comparison on an industrial scale, or ordinary experiment on a reduced scale, affords direct results conclusive only for the given conditions. Indirect results from comparison of ratios of proximate constituents referred to some experimental results, like Johnson's, are scarcely to be regarded as approximate even for the conditions assumed by such standards of reference—if for no other reason—for want of gradations enough among available standards for comparison to furnish exact counterparts of given conditions.

It is surprising to find Johnson's comparisons of the evaporative efficiency of some 40 examples known to the coal trade of some 34 years ago, still doing duty in this country by way of furnishing exemplars of a specific performance of coal with a given proximate constitution. But it is still more surprising to find the army to-day following the navy a third of a century behind, with another series of experiments on the same now antiquated plan. I refer to the researches into the evaporative efficiency of some 34 American and a few foreign coals, with reference to their merits as military sup-

plies, in the interest of the Quartermaster-General's Office, under the immediate auspices of which they were made at Washington. (Fuel for the Army. War Dep't, 1882.) From the fact that these represent, along with standard or at least well-known American and foreign coals, a great variety of types of American mesozoic and tertiary coals and lignites of whose technical properties but little is generally known, the selection of examples was particularly adapted to a comprehensive exhibition of their performance under approximately equal, even although special, conditions. But the work as executed, even on the narrow plan adopted, falls lamentably short of what it might have been easily made by analyses of the examples, so as to have connected their constitutional characteristics with the results reported. For want of definition by analyses, it is difficult to see what practical significance, if any, these results may have even for the War Department, as the record stands for nothing more constant than certain commercial coals, products of certain mines and certain local occurrences of coal.

Investigations of the calorific power of coals specially commend themselves to the administrative departments of the general government. Under no other auspices are equal facilities available either for the collection of a desirable variety of materials from a wide geographical range, or for their experimental study on a scale of magnitude befitting the requirements and importance of the work. The precedents afforded by the researches first conducted by the navy, and recently by the military departments of the government, may warrant the hope that one of these, or some other division of the public service, will ere long be charged with the duty of an extended investigation of the same subject on a plan for which models have been furnished by other countries.

As plenary power of selecting its field of work seems to have been delegated to the U. S. Geological Survey, it may be proper to commend such an investigation to the attention of this branch of the public service. Some of the yet unpublished work executed by the survey under a former direction, in co-operation with the Tenth Census, is in spirit not unlike what such an undertaking should be. One of the principal objects to be sought is the positive relations of calorific power of coals to their units of ultimate and proximate constitution. Whether these can be so formulated in terms of either or both of these quantitative expressions of coal, is yet indeed uncertain. But experimental methods are now practiced for a treatment of the subject in the spirit of contem-

porary physical research.* The subject can be adequately treated in no other spirit, nor on any but a comprehensive and systematic plan.

THE NORTHERN SERPENTINE BELT IN CHESTER COUNTY, PA.

BY DR. PERSIFOR FRAZER, PHILADELPHIA.

MR. THEODORE D. RAND has made some interesting observations on the serpentines of Chester and Delaware counties, Penna.,† in which he suggests that the outcrops of this rock are detached from each other, and that while a comparatively narrow belt, running nearly east and west, will include them all, the strike of each outcrop differs considerably from the direction of this narrow belt; and that it results that these isolated exposures exist on the map, as it were, in echelon, the easternmost end of each lying northwest of the western extremity of its neighbor. As he elsewhere remarks, this is important, if established, and the writer spent a day or two recently on the ground in the study of this phenomenon. One thing would seem to follow from such a state of facts, viz., that this serpentine at least must have been of secondary origin, for it is difficult to conceive of a rock which occurs intercalated in numerous horizons of a different formation, and agreeing with the latter in bedding, unless the former were an altered product of the latter. It is true that one might account for it by the supposition of an original unconformable deposit, which had been broken by a number of faults and distorted by throws to the northwest; but this hypothesis would do violence to the observed facts relating to the measures along with which the serpentine occurs, and in which no such distortion has been observed.

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* Thus for determining, by evaporative test, the calorific power of a coal, the ultimate constitution of which is known, it is requisite, that, besides the quantity of coal consumed and the weight of the water evaporated, the temperature and chemical composition of the escaping gases, or gaseous residue, shall be quantitatively determined, the same as solid residues of ash and unconsumed fuel.

In observance of such requirements, the *Heizversuchstation* of Munich has been in operation since 1879. This consists of a permanent boiler plant, constructed on the principle of the calorimeter, with special provision for avoiding errors from loss of heat—such, namely, as arise from radiation and conduction, and from the varying proportions of water in steam.—Muck. Steinkohlen-Chemie, 1881, 146.

† See Proc. Min. and Geol. Sect., Acad of Nat. Sci., 1880 and 1881, pp. 9 and 28.

It is hoped that the following details will not be without interest, at least so far as the localities in Lower Merion (Delaware County), and Easttown (Chester County), Penna., are concerned.

The region of Pennsylvania in which these serpentine belts occur is also an important one, on account of a tongue of old amphibole gneiss, which extends westwardly, at a small inclination, to the line of the Pennsylvania Railroad; and penetrates Chester County for some miles, dying down not far from West Chester. Everything yet known about the rock induces the belief that it is a true representative of the oldest or Laurentian series. Upon it are deposited various micaceous gneisses and schists, and, finally, serpentine belts occur, both to the north and to the south of it, in Montgomery and Delaware counties. If the indications may be trusted in Chester County, the axis of the belt is oblique to the axis of this gneiss, and the former crosses the latter a short distance further west, in Chester County. Between Wayne Station and Radnor Station (formerly called Morgan's Corner) a number of interesting and typical rocks are obliquely passed in the cuts where their outcrops are made visible. A road which was being newly cut (in September, 1883) from the Lancaster turnpike to the new station at Wayne, Pennsylvania Railroad, showed a large number of massive bowlders of syenitic gneiss imbedded in the soft earth.

The traces of lamination in these bowlders are numerous, but the rock is very compact and hard, and resembles intrusive syenite. Near Wayne these bowlders were found about six feet below the surface.

About 150 feet northeast of the freight depot of Wayne, in another cut, is found a different variety of firmly-bedded, dark, very friable gneiss, in which quartz is almost entirely absent. It forms merely a band in a mass of gray, thoroughly-disintegrated gneiss. Quartz is very sparsely distributed through the rock, but its main constituents are plagioclase (chiefly oligoclase), and lime feldspar, hornblende fragments, and some biotite. The amphibole gneiss which follows to the east end of the cut, dips N. 10° W.—75°. The previous exposures, while satisfactory for lithological determinations, were worthless for stratigraphy, on account of sag or slip. The entire cut consists of alternations of soft, decomposed, grayish stuff, and dark-colored, thin-bedded gneiss.

About 100 yards east of the new station of St. David's, is a rock, of which the constituents are a highly lustrous mica of garnet color, and a gneiss of white felspar, compact and hard. It

dips really about N. 10° W.—35° (though for a considerable distance along the line of the road, the sagging of the bed has produced a very deceptive appearance of dip, E. 40° N.). To the north of these latter, are beds of weathered, thin-bedded, grayish gneiss. These strata reach to Radnor, and cover a thousand feet, more or less, of the ground to the northwest or *above* them.

A quarter of a mile northeast from the station at Radnor, on a small knoll, a dark-colored serpentine schist appears with a wavy strike of E. 5° N. The direction of the dip is difficult to determine, but it seems to be mostly to the north. The breadth of this black material is about 2 feet. The serpentine and steatites immediately following (northeast) the black layer are light-colored on the surface but dark-colored below. At an oblique angle of 45° to the line of the strike and a distance of 135 feet, is a serpentine and talc-schist, dipping S. 10° E.—80°, very much decomposed.

At 312 feet in the same oblique direction, a very much decomposed rock, retaining many mica-schist characters and even traces of hornblende fragments, but consisting essentially of talc-schist and chrysotile. Its apparent dip is N. 15° E.—75°. Just beyond a branch of the Gulf Creek, which here forms the boundary of the serpentine, a heavy-bedded hornblendic gneiss appears, disappearing N. 20° W.—87°. This is the northern boundary of the serpentine, and is formed, in all probability, by the same Laurentian gneiss noticed in the Schuylkill near Spring Mill, to the east, and at the Spread-Eagle Post-office, in Chester County, to the north.

The entire serpentine deposit is about 141 feet in perpendicular thickness, and forms a belt of rocks alternating between characteristic serpentine, and talc-schist, strangely various in character and habit. A quarry a short distance south of the middle line of this belt dips N. 20° W.—78°.

To sum up the exposure of serpentine, there are great differences both of composition, habit, and position, in the rocks of this belt. The latter varies from S. 5° E.—65° on the southern edge to S. 10° to 15° E.—75° to 85° on the northern edge.

"It is doubtful if this variation of dip has structural significance, but if so, it implies a sharp anticlinal here. About 106 feet perpendicularly across the strike is a schist which, while justifying the appellation of talc-schist, resembles in its habit that which it in all probability originally was, viz., nacreous, perhaps a chlorito-nacreous schist."*

* See author's remarks in Journal of Franklin Institute. Phila., October, 1883.

About half a mile northwest of Radnor Station is a quarry of serpentine on the summit of a hill, which is the next important exposure nearly due west of that just described. The structure here is quite interesting. While the bedding is obscure, the rock can be easily divided into a southern and a northern half. The dip of the latter was about S. 10° to 20° E.—54°. The rocks are very much waved. The southern point of the exposure dips ± N. 30° E. ± 83°.

Although the thickness of the S. 10° E. dips seems to be greater in the quarry than that of the N. 30° E. side, there is room to suppose, that, with the addition of the outside adjacent rocks of the same portion which are not opened up, there is either a sharp canoe-shaped synclinal represented here, or a sudden and complete reversal of the direction of the beds.

There appear to the writer to be also abundant traces of alteration in the rock, together with actual remains of both amphibole and mica-schist. But while the change has been usually complete, there are portions of the rock which are almost unaltered. An interesting specimen of white serpentine, in the form of a somewhat flattened prism, with a nucleus of yellow serpentine, of which, in turn, the nucleus was changed to chrysotile, was found. This quarry, with the detached veins of serpentine lying to the north of it, is almost due west of the first-mentioned outcrop, and distant about three-eighths of a mile.

The next important outcrop of serpentine is about one mile and a quarter west of this, in Chester County, and one-third of a mile south of the old Eagle Station, Pennsylvania Railroad, though there are one or two minor exposures, giving doubtful data as to structure in the interim. Thick and very much waved beds of serpentine here dip E. 30° S.—55° to 60°. The surface-rock, as usual, is very much stained with various decomposition products of serpentine. Talc-schist, picrolite, and chrysotile occur frequently, and also a dark purple variety of the principal rock. The strike appears to range throughout the quarry S. 30° W., and there are no certain signs of anticlinal or synclinal structure, but the talc-schist, which is abundant, assumes, in places, a chloritic habit. The direction, and other details of the dip are uncertain, but the strike is clearly apparent.

Passing over two minor exposures to the west, there is one of interest a few feet east of the road, which runs a little east of south from Berwyn Station, and about a mile therefrom. This serpentine quarry is north of a fragment exposure of trap, which is so light,

however, as to give no reliable information as to its extent and position. It is on the southern border of the hydromica schists which form the South Valley Hill, while, to the south of it, and beyond the trap fragments just alluded to, is a compact laminated quartzose gneiss, of very light color, having layers of dark-colored matter (biotite, principally). The large amount of feldspar of the rock is very much decomposed into a white pulverulent clay. The dip is N. 10° W.—75°.

A few hundred feet south of this, and south of the Paoli road, is a quarry in heavy-bedded hornblendic gneiss which dips S. 10° E.—82°. Underlying the serpentine to the south, there seems to be first a friable, white, quartzose gneiss, with biotite and very sparsely distributed fragments of hornblende, and south of this a heavy-bedded syenitic gneiss, containing well-defined crystalline quartz, feldspar, and striated hornblende, besides garnet and other accessory minerals. If this rock be the westward prolongation of the Laurentian syenitic gneiss before-mentioned near Radnor, and St. David's near Wayne, it would appear to have preserved about its normal strike to the southwestward, and it would also appear that the serpentine belt (together with the country rock, of which it forms part) is crossed by it, and now appears on its northern flank.

The serpentine of the quarry above mentioned (about a mile south by east of Berwyn Station, and a few hundred yards north of the Paoli road) exist as a belt apparently much narrower than that northeast of Radnor Station. The quarry itself exposes the rock for a perpendicular thickness of about 15 feet, besides which some ten feet more of crop may be safely added. A large number of dips taken where the rock is well exposed, gives a mean about E. 40° S.—88°, and the outcrops concur in making the strike N. 40° E., though those to the north, which are the most distinct seem to put the posture of this rock as vertical.

If these elements could be trusted as those of structure, it would imply an anticlinal cusp here. The most interesting part of the quarry, however, is the alternations which it exhibits, of layers of serpentine and of a talc-schist, so like chlorite in habit that the illusion, at a short distance, is very strong. There are no less than three of these bands of chlorite-like talc-schist within the fifteen feet of the opened quarry, besides one bank on the north margin of the quarry, and several among the visible outcrops still further north. A specimen from the subordinate band which lies at the northern edge of the quarry, was selected and analyzed for the alkalies, in the writer's

laboratory, by his assistant, Mr. C. Hanford Henderson. The result was a surprise, since it established that

	Per ct
Magnesia = ...	17 89
Soda = ...	6.026
Potash = ...	0.613

Taking the mean of several reliable analyses of paragonite (one of the dominant minerals in the body of rocks lying to the north of this strata and serpentine), and, assuming for the moment, that all the soda was derived from this mineral, enough is present to give us 82.36 per cent. of paragonite in the rock. And assuming the mean percentage of potash in paragonite to be 0.57, a very much too liberal allowance, obtained from the same data, we would have enough left over to account for the co-existence in this rock, of 0.37 per cent. of damourite. On the other hand, comparing the percentage of magnesia with that of the mean of forty well-authenticated analyses of talc, and with eleven of slaty serpentine, it appears that the rock in question contains only 57.48 per cent. of talc and has not magnesia enough for more than 46.88 per cent. of serpentine if this were the principal constituent.

Of course there is no such percentage of hydro-micas present. A full analysis would be necessary to determine how the soda is combined, and from what minerals it is probably derived, but the fact remains that this rock is not more than 58 per cent. talc, and contains abundant evidences of dérivation from nacrites.

A specimen from the first exposure mentioned in this paper or about one-fourth of a mile from Radnor Station, Delaware County, was analyzed at the same place, and by the same chemist. In this specimen (although it was taken from nearly the median portion of the serpentine belt), the small crystals of nacrite are abundantly visible throughout the schist. An analysis showed

	Per ct.
Magnesia, ...	33.66
Soda, ...	4.44
Potash, ...	0.638

The percentage of magnesia is here 2.54 higher than the average of forty analyses of talc above employed, and some of this excess may be due to the existence of magnesite or other decomposition product.

The percentage of soda would be sufficient to account for 38.68 per cent. of paragonite, if all were to be ascribed to that mineral, while a slightly increased fraction of a per cent. of damourite could be constructed out of the remaining unused potash.

These results seem to lend a high degree of probability to the theory that at least this belt of serpentine is a metasomatized product of a layer or layers of the hydro-mica schists in contact with which it lies, and with which its relations are otherwise abundantly made out by very different processes of comparison, viz., stratigraphically, geographically, and chemically.

[Specimens from the belt which formed the subject of the paper were shown, illustrating the similarity in habit of these talc schists and serpentines to the chlorites and nacrites.]

THE PEACH BOTTOM SLATES OF SOUTHEASTERN YORK AND SOUTHERN LANCASTER COUNTIES.

BY DR. PERSIFOR FRAZER, PHILADELPHIA, PA.

THE section along the left bank of the Susquehanna, in Lancaster County, from Falmouth to the Maryland line, which the writer made in 1877 to accompany his report on that county, was redrawn by Professor Lesley, as stated in the prefatory letter to Vol. CCC. (p. x.).* As then stated, neither the numerous data, nor the general features of the structure obtained by the writer, were changed; but enough was done to make a discrepancy between the text and the section as given; and some important points were made less clear in the published section than they were in the MS. map. Amongst other portions of the section, that between the railroad stations, 1190 to 1224, gives the impression on the published maps of a much too definite superposition. A few words will be devoted to this region in the following communication.

There is absolutely no room to doubt the structure for about four miles on each side of the Tocquan axis. The dips are gentle, and in opposite directions, and the lithological characters constant within ordinary limits of variation, nor do these characters resemble those of the rocks which flank these gneisses and mica schists to the northwest and the southeast. For the same reasons it is evident that the rocks which occur within these eight miles or so, represent an horizon below the basement of the fossiliferous or palæozoic series. Not only have no fossils been found, but their lithological characters are unmistakably eozoic. But on the upper and lower margins of this

* Publ. of the Second Geological Survey of Pennsylvania.

thick series there are palpable signs of disturbance in bedding, and after an interval (commenced on the York County side by a trap dyke, and marked by an absence of exposures), the roofing-slates of Peach Bottom come in among a series of chloritic schists, resembling other portions of the chloritic series closely in mineral constituents, but showing rapid changes in position, and much contortion, in place of the uniformity of structure to the northwest. It is noticed in report CCC., that a quartz-slate containing, like the Chikis quartzite, intercalated beds of hydromicaceous matter, is found constantly near, and apparently *above*, the roofing-slates. Whatever be the relation between this quartz-slate and the Potsdam, this horizon marks the northerly limit of a region which, extending towards the Maryland line, includes the greatest diversity of dip and strike. This was so manifest to the writer in 1877, that he suggested the possibility that the whole region had been filled by a plicated band of rocks of only a few hundred feet in thickness. [See pp. 141 and 142, etc., where the grounds and objections to this view are discussed.] All that can be stated with certainty is, that after $\pm$ 3600 feet perpendicular thickness of chlorite measures, overlying a thick gneiss anticlinal, there is an absence of exposures for a surface-distance of more than a mile, after which appear rocks resembling the chloritic series in general lithological characters, but showing that these have been subjected to entirely different conditions.

High up in this contorted series, and a short distance (geologically) below the quartz-slate, occur the Peach Bottom roofing-slates, while the latter may be easily conceived to maintain the present surface as its horizon for the remainder of the section. Add to these facts that dykes of dolerite occur at the lower and upper horizons of the contorted series, rendering the supposition of clefts and their concomitant faults probable, and what the writer has given of stratigraphical notes is complete.

The objections to considering the measures consecutive, and without a break from the base of the chlorite to the Peach Bottom slates, is the suspicious gap in the exposures, and the following change in the structure.

The objection to the hypothesis of a fault bringing down the Palæozoic measures to a level with the Huronian are, first, the lithological similarity between the rocks on each side of the northerly fault, and also the absence of any evidences to the northeast or southwest of the Susquehanna of the existence of such well-marked

formations as the Primal S. S. and the Auroral limestone. That is, unless the Doe Run limestone in West Marlboro Township, Chester County, be considered such evidence. This formation is, indeed, nearly on the strike-line of this belt, and, if it be connected with the phenomenon here alluded to, and not (as suggested in the report on Chester County) a sub-Primal limestone, its position is due, not (as several geologists have assumed) to a normal position above the South Valley Hill (Hudson River (?)) schists, but to the thrusting up of a great belt of Huronian rocks, extending from Turkey Hill to somewhere near Fishing Creek on the Susquehanna, or from Parkesburg to Doe Run in Chester County, cutting the original Chester Valley limestone off from its southern continuation, and substituting for it the eozoic measures.

From this stratigraphical maze one turns with eagerness to any palæontological evidence which may be obtainable. In point of fact, several very interesting plant forms have been observed in the Peach Bottom slates, the latest specimens having been furnished the writer by Professor I. N. Rendall, President of Lincoln University, Chester County. [*These specimens were exhibited to the Institute.*] They were sent to Professor James Hall, of Albany, who was kind enough to examine them, and furnish the following communication.

It is much to be regretted that the fossils are not more distinctive, but even had they accurately defined the horizon whence they were taken, it will be seen above that they would not have sufficed to explain all the knotty problems connected with the structure on this part of the Susquehanna. They leave the question of the age of these slates to be fought out on the battle-ground of the Quebec group, about which there are still such wide differences of opinion.

ALBANY, September 18th, 1883.

DR. PERSIFOR FRAZER.

MY DEAR SIR:

* * * * * * * * *

THE specimens,* of which the representations will be found in the accompanying plates, present the appearance of the older shales of the Quebec group, but, so far as lithological aspect is concerned, may as well be of Hudson-River age.

The conspicuous fossils have the character of marine vegetation, and the aspect of Algæ. I find that the forms have been replaced by a film of iron pyrites, and the larger lobed and branching one (upon the largest specimen of slate marked A) shows considerable thickness of this pyritous film, which appears as if it might have filled a vesicular substance, and have been flattened under pressure, the margins being well defined. These forms might be compared to dendritic markings, which sometimes occur in slates and sandstones, but the thickness of the substance and the distinct limitation of the part suggest an organic origin.

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* The specimens referred to by Prof. Hall are figured in the accompanying plates.

The most nearly allied forms, so far as I have observed, among known organic bodies, are the recent HALYMENIA and the fossil genus HALYMENITES. This form is also not unlike some of the BUTHOTREPHIS of the older limestones. You may, however, perhaps regard its manner of occurrence, its regularity and numerous fronds, or portions of fronds, all in the same position, and free from crossing or intercalation of parts, as a fact in favor of mineral infiltration, assuming dendritic or plant-like arrangement.

One will notice that the lower edge of the specimen has been cut by a slip or fault, leaving an oblique striated surface on the opposite side.

The other forms on the specimens B and C are distinctly organic in their character and mode of occurrence, and belong to some algoid form. They have some resemblance to Laminarian forms, as represented in *Laminarites Lagrangei*, by Saporta and Marion, and are too rigid in mode of growth to be referred to CHONDRITES.

Those on B are not very unlike some forms which have been referred to BUTHOTREPHIS, only much larger and stronger than any which I know.

The specimens on C are fragmentary, smaller, and somewhat more rigid than the others, but apparently of the same species as those on B. Both of these are more rigid than ordinary forms referred to BUTHOTREPHIS, but I do not find anything else with which to compare them.

On the specimen marked D I find only a kind of efflorescence of gypseous matter, but no distinct organic markings.

The specimen E presents a more or less distinctly limited circular area, mainly distinguishable from the surrounding surface by its difference of color. Under a lens, this area shows no evidence of structure other than the ordinary slaty surface: but in certain light I think I can see, by the naked eye, faint markings as if of branches, radiating in an irregular manner from the centre, and bifurcating in their course. This reminds me strongly of some Graptolitic forms, such as *Graptolithus rigidus* and *Graptolithus Logani*, in the absence of the disk. On the same specimen E, marked by a round red ticket, and between the ticket and the margin of the disk referred to, there is a fragment of a Graptolite with serrated margins.

I have also indicated, by red tickets, two points upon the recently separated surface of B, which appear to be marked by Graptolitic fragments. The numerous black points have the same appearance as the fragments of Graptolites on our Graptolitic slates of the Hudson-River group.

Although I can find nothing which will give positive information of the actual horizon of these slates in the geological series, there can be no doubt but they occupy a place either in the Hudson-River or Quebec series, and not unlikely in the latter.

I regret that I am not able to give more positive information, but the facts within my knowledge do not warrant a positive expression.

I am, very truly yours,

JAMES HALL.

The section which accompanies this paper was drawn from the original; not from the section as altered by Professor Lesley, and represents in the opinion of the writer more nearly the geological structure of the lower Susquehanna. The upper line contains the low water mark line of the left bank, with the railroad distances from the Susquehanna Rolling Mill in Columbia marked by figures,

between which the cross lines indicate every 100 feet. Upon this bank are located the exposures with the direction of the dips. The straight line immediately below this is the projected line of the dips taken on this bank, which was calculated by taking the mean of all the dips obtained from "Cutler's" to the Maryland line.

The lowest line represents the line of projection of the dips taken on the right bank of the river over the same distance, and the direction of this projection line was obtained in a similar manner from the exposures on the York County side. These two were brought together so that the Peach Bottom slates were opposite to each other on the maps as in nature. The left hand end of each section represents the eastern termination of the mica-schist series, and the commencement of the chloritic and quartzose rocks. The average distance apart of these section lines is about a mile, but their agreement in general stratigraphical features is evident. There is the same change of character at the left hand or northwest end, between the mica-schists and chloritic series, and the same evidences of unconformable superposition in the line joining the chlorite mica-schist contact in the two sections which is oblique to the river, and to the general strike of the rocks.

A WATER-GAS FURNACE AT ELGIN, ILLINOIS.

BY P. BARNES, JOLIET, ILL.

In a paper recently read before the Institute by Mr. W. A. Goodyear, a useful presentation was made of the subject of the production of water-gas on a large scale, by the use of a regenerative form of apparatus. By way of supplement to that paper, a brief statement of the details of a plan which was carried out at the works of the Elgin National Watch Company at Elgin, Ill., may be of interest, although the ultimate result of the working of the producer was not successful or satisfactory.

This company had decided to build a gas-works for the supply of illuminating gas to their factory, on a much larger scale than that of the petroleum-works which had very successfully supplied the smaller buildings for many years, and in March, 1882, the material for a gas-making cupola furnace was purchased. A few weeks later it was decided to make the attempt to burn the gas under the steam-

boilers of the establishment, and a second set of material was ordered.

In July, 1882, when the writer took charge of the work of construction, it was agreed, after a study of the probabilities of the situation, to make an attempt to utilize the waste heat developed in the process for preheating the air-blast and the steam used, to the highest possible point, so that the fullest practicable limit of economy should be reached. This was believed to be the more needful, because of the obvious requirement that the gas should be furnished at the least possible cost, to meet the competition with coal fired direct under the boilers.

The material which had been purchased was utilized as fully as it could be in building two firebrick stoves, and the fire was put in a rectangular fire-box, which was attached to the stoves by short direct flues. The plans for this work were completed in August, 1882, and the furnace was set at work in February, 1883.

It was soon found that although the proposed preheating of the blast and of the steam was very fully accomplished, yet the shape which had been adopted for the fire-box was not such as to secure the intense concentration of the heat needed to secure the complete fluxing of the furnace which had been undertaken. It was also found that the chilling of the slag, which was run down in considerable quantities by the steam blown in during the gas-making, was so complete that it became quite unmanageable, and that it would lodge in the base of the fire-box below the line of fusion, and also above this point, with so little fuel remaining in or near the masses of slag that they could not be remelted when the blast was turned on again. This action of the steam in cooling the slag was anticipated, but the trial was thought to be worth making.

A considerable quantity of gas was made in the furnace with the regenerative fixtures as first erected, the holder which had been provided for the storage of the illuminating gas being used for the fuel gas during the trials which were made. This was burned under the boilers using simple perforated iron pipes for burners. A considerable evaporation was reached, but it was found that in order to compete with direct coal firing, even with the market price then current for coal used under the boilers, of $5 per ton, the gas must be furnished for decidedly less than 5 cents per thousand cubic feet, even if the cost of labor, as compared with direct firing, were to be wholly omitted in making up the estimate.

The saving of the waste heat was found to be very complete, the

products of combustion and the water-gas both escaping from the apparatus at a temperature very close to the boiling-point of water.

It was found that the splintering of the brickwork in the lower part of the fire box, due to the removal of the very stubborn clinkers which were formed, would lead in any event to a very short life of that part of the apparatus as then constructed, and in view of some other important local reasons it was considered advisable to abandon the regenerative fixtures, and the expectation of using the gas under the boilers. The furnace was then rebuilt and fitted up for making illuminating gas only, upon the plan which had been used for some years in Chicago under the patents of Mr. T. G. Springer. The whole was put into very successful operation in July, 1883.

ROASTING IRON-ORES.

BY JOHN BIRKINBINE, PHILADELPHIA, PA.

"WHETHER an iron-ore should be roasted is a question which very seldom arises; at least, this question seldom ought to arise. With the exception of the red impalpable oxide, the whole series of iron-ores require roasting—even the specular iron-ore, if it is very compact—but the best oxide, if too compact, works badly in the furnace. All other ores should be subjected to calcination. Some ironmasters are in the habit of using the hydrates raw, but this should not be done where clay-ores are smelted or where the hydrates contain either chlorides or phosphates. But in the latter case, the pig metal will be cold-short if there is too much phosphorus. Under all circumstances, however, it is best to roast the ores if we expect good metal and well-regulated furnace operations.

"The object of roasting ores is to produce higher oxidation and to expel injurious admixtures. In both cases liberal access of atmospheric air is required; we should, therefore, so arrange our roasting operations as to fulfil these conditions, from which it will appear that different ores require different treatment."*

The above may be considered an extreme, and perhaps erroneous view; but there is no question as to the absence of a general appreciation concerning the value of preparing ores of iron for smelting in the blast-furnace.

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* *Metallurgy of Iron and Steel*, Osborn—page 257.

Roasting ore is by no means a new feature of iron-manufacture, but rather may be considered as having fallen into comparative disuse; for the older blast-furnace practice almost universally embraced preliminary calcination of ores.

That roasting of iron-ores was practiced in the seventeenth century is evident from the following extract taken from John Ray's *Collection of English Words*, 1672:

"When the mine is brought in they take small coal (charcoal) and lay a row of it, and upon that a row of mine, and so alternately S. S. S., one above the other, and setting the coals on fire therewith, burn the mine.

"The use of this burning is to modify it so that it may be broken into small pieces; otherwise, if it should be put into the furnace as it comes out of the earth, it would not melt but come away whole.

"Care, also, must be taken that it be not too much burned, for then it will loop, *i.e.*, melt and run together in a mass. After it is burnt, they beat it into small pieces with an iron sledge and then put it into the furnace."

In Sweden the blast-furnace is generally said to be able to "run by itself" when the roasting-kiln works satisfactorily.

The roasting or calcination of iron-ores is carried on to accomplish the following purposes:

A. To facilitate the breaking of lump ore, or to make it more porous and easier reduced.

B. To remove water.

C. To drive off carbonic acid.

D. To desulphurize, partially or thoroughly.

E. To expel other volatile matters.

The first-named object is generally a matter of local convenience or economy, and it need not be especially enlarged upon. But it is not improbable that there is often a partial oxidation in roasting many ores which has a beneficial influence.

The treatment of hydrated ores permits of material improvement in blast-furnace operation, but the claim is often made that, as the moisture is driven off in the upper zones of the blast-furnace, little real value results from roasting hydrated ores except in low furnaces; some managers even asserting that wet ores are advantageous to keep the tunnel-head cool. There are other and better methods of keeping the top of the furnace at a low temperature than by charging into it what is worse than useless, and placing additional and unnecessary duty upon the plant; and it is hardly to be presumed

that such practice is the result of a thorough study of blast-furnace economy.

To obtain good results from most of the carbonate-ores, preliminary roasting is a necessity; and in no locality is the process carried on more generally than in the Cleveland District, England. The results there obtained are exhibited by the following:

Analyses of the Raw and Calcined Cleveland Stone.

	Cleveland ore or stone uncalcined.	Cleveland stone after calcination.
Ferric oxide (Fe_2O_3),	2.60	66.25
Ferrous oxide (FeO),	38 06	
Manganous oxide (MnO),	0.74	
Manganic oxide (Mn_3O_4),		0.65
Alumina (Al_2O_3),	5.92	7.72
Lime (CaO),	7.77	6.46
Magnesia (MgO),	4.16	4 78
Potash (K_2O),	trace	0 02
Carbonic anhydride (CO_2),	22.00	
Water (H_2O),	4.45	
Silica (SiO_2),	10 36	11.87
Sulphur (S),	0 14	
Phosphoric anhydride (P_2O_5),	1.07	1.13
Sulphuric anhydride (SO_3),		0 90
	97.27	99.78

Experiments made by Messrs. Tunner and Kupelwieser in an Austrian charcoal-furnace of small dimensions indicate that practically one-third of the height of the furnace was used in driving off the volatile matter from raw carbonate-ores. The following shows the data obtained in these experiments, and is a sufficient argument in favor of roasting this class of ores.

Depth below the top of the furnace, in feet.	TEMPERATURES IN CENTIGRADE DEGREES.			
	Crude ores.	Half crude, half roasted.	Roasted, charged cold.	Roasted, charged hot.
0	.....	.....	50	500
2	.....	.....	.....	.....
4	.....	.....	90	.....
6	56	.....	160	.....
8	.....	225	340	.....
10	90	350	.....	.....
16	.....	.....	640	.....
18	.....	600	680	770
22	.....	700	840	.....
26	.....	.....	950	920

The most important province of roasting seems to be desulphurization, but in heating the ore to a sufficient temperature to drive off sulphur, other volatile matters are also eliminated.

"The effect of sulphur on iron has, in many instances, been overlooked or underrated. In charcoal-blooms a quantity of sulphur so small as 0.035 per cent. may be sufficient to produce cracks in the bar-iron rolled from them. These cracks can be easily distinguished from those resulting from interposed cinder, because the former do not disappear by repeated welding. In puddled iron the amount of sulphur can be somewhat higher. As it is possible to weld and roll puddled iron at a heat above the point dangerous for red-shortness without burning the iron, the evil can, to a certain extent, be avoided. In Bessemer and open-hearth steel the influence of sulphur is believed to increase as the amount of carbon diminishes. In Bessemer steel for rails containing about 0.35 per cent. carbon, the highest amount of sulphur tolerated is reported to be 0.05 per cent.

"To make gray pig-iron the ore-burden in the blast-furnace must be smaller in using sulphurous ores, thereby increasing the consumption of coal. Another source of loss arises from the necessity of melting a large amount of limestone. The effect of sulphur on pig-iron is to induce the combination with carbon, thereby tending to make white iron, but it is not probable that the chilling properties are thereby increased. For car-wheels there is, however, not required a pig-metal already combined with carbon, but one that is ready to combine when cast against a chill-plate."*

As the present purpose is to discuss some of the methods pursued, the appliances used, and the results obtained in roasting iron-ores, the expression "roasting" will be used as indicating the partial elimination of sulphur, the calcination of carbonates, and the drying of hydrated ores, in contradistinction to "desulphurization," or the more perfect removal of sulphur from ores.

The subject will therefore be divided into two sections:

1st. *Roasting.* The calcination, or treatment of ores by heat in such manner as to remove, practically, one-half of the sulphur, or so much as can be driven off by heat alone, or to eliminate carbonic acid, water or volatile matter.

2d. *Desulphurization.* The treatment of ores by heat and subsequent exposure to oxidation or other influences which eliminate additional portions of the sulphur.

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* N. Lilienberg in the *Journal of the United States Association of Charcoal Iron Workers*, vol. iii., p. 258.

This naturally forms a general division of the methods employed, into those which use solid fuel in contact with the ore under treatment, and those which are operated by gaseous fuel.

There are practically three processes used for *roasting* iron-ores with solid fuel.

A. In open piles, clamps, or ricks, varying from a few tons to thousands of tons in one heap.

B. Between closed walls, which are simply boundaries for piles.

C. In kilns or structures, with open, or practically open, tops into which ores and fuel are charged.

In either case the fuel used is generally what is considered waste, viz: old wood, anthracite culm, bituminous slack, charcoal braize, and in some instances small coal bought especially for the purpose. The "buckwheat" coal of the anthracite regions, used to a considerable extent in eastern Pennsylvania, is an example of the latter.

The subdivision of roasting with solid fuel will demand attention at present, that of desulphurization in kilns using gaseous fuels may be considered in the future.

Roasting in Piles or Ricks.

For roasting or calcination in open heaps, ore and fuel in alternate layers are placed upon a bed of wood or coal, until the pile so formed reaches to a desired height. The proportion of ore to fuel in the several layers is generally made to increase from the bottom towards the top of the pile.

"In the Hartz districts the first layer on the ground consists of a bed of slag, upon which is placed a layer of iron-stone, and then alternate layers of fuel and ore until the whole forms a truncated pyramid of some nine feet in height, with a base measuring about sixty feet square. The ores to be treated are calcareous, and the process has a duration of from eight to fourteen days, and for the calcination of each cubic foot of such ores about one-third of a cubic foot of small coal is consumed.

"Ores containing much carbonaceous matters, sulphur, or other combustible substances, are treated in longer heaps, with less width at the base, than those above described, whilst the height of the pile rarely exceeds about three feet; such heaps are preferable for the roasting of these classes of ores, since they do not attain to so high a temperature as the larger heaps, and the ore is not, therefore, so liable to become fused together. Further, also, this class of ores requires to be calcined in larger masses than is the case with argil-

laceous and other ores free from combustible matters; but other ores, such as those of Westphalia, which are less rich in carbonaceous matters, are usually treated in large heaps of from 20 to 30 feet in width, from 15 to 20 feet in height, and of various lengths, in which the calcination is continued from two to three months before it is completed."*

Additional details concerning foreign methods are given by Crookes and Röhrig as follows:

"At Witkowitz, magnetic iron-ores are roasted for three or four months, in heaps about 120 feet long, 30 feet broad, and 6 feet high; 100 pounds of ore, consuming 0.01 cubic foot of wood in pieces, 0.72 per cent. of coal of middling size, and 3.71 per cent. of small coke; one quarter more of small coal is used when roasting argillaceous sphero-siderites.

"At Heinrichshütte (Westphalia), the black-band ores are roasted in heaps from 20 to 30 feet broad on the basis, from 10 to 15 feet high, and varying in breadth, for from one to three months, according to the nature of the ores and the size of the heaps.

"In Westphalia, heaps of the following construction are employed in order to obtain a more uniform roasting: The heaps are 120 feet long, 30 feet broad, and 5 feet high, inclosed between walls built up of the larger ore-pieces, small openings of one square foot being left at intervals of 12 feet, along the sides. These draught-holes communicate with passages 3 feet deep in the interior of the heap, which are filled with wood. The larger blocks are placed in the middle, whilst small ore is heaped against the sides of those passages in order to conduct the flames as much as possible into the heart of the heap. After the heap is fully ignited, the wall is pulled down and thrown upon those places where the fire shows a tendency to come too quickly to the surface, in order to dampen it. A heap of the above dimensions contains about 17,000 cubic feet of ore, and takes about a month to burn out.

"In Scotland and Staffordshire, black-band ores are roasted in heaps from 3 to 9 feet high, resting upon a foundation of coal, at an expense of 8d per ton, namely, 4d for labor and 4d for coal.

"The roasting in heaps is also employed at Yniscedwin and Ystalifera, in South Wales, but in England and Wales most of the ores are roasted in kilns. At Yniscedwin four or five cwt. of coal are used for roasting one ton of ore; roasting in kilns costs 2¾d per

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* *Steel and Iron.*—Greenwood.

ton of ore, and is much cheaper than roasting in heaps, which causes an expense of 6d per ton.

"The great disadvantage of calcining or roasting in heaps is the comparatively large consumption of fuel which the process entails, amounting in the South Wales and Staffordshire districts to about $2\frac{1}{2}$ cwts. of coal, consisting of 2 cwt. of small and $\frac{1}{2}$ cwt. of large coal to the ton of ore. There is also a difficulty in regulating the temperature throughout the pile."

In some cases pile-roasting is carried on under cover; but ordinarily the heaps are exposed to the elements and much of the good result obtained is lost by subsequent absorption of moisture. Some furnace-managers claim a more thorough elimination of sulphur in open piles but confess a greater expense in fuel.

At the works of the Cambria Iron Company, Pa., the carbonate-ore is burned in great heaps based on a foundation of cord-wood. Coal is mixed with the ore as the pile for burning is formed, using 15 per cent. in weight of coal.

The average cost of mining both benches of this ore during part of the year 1882 is given by Mr. John Fulton at \$2 $47\frac{1}{2}$ per gross ton.

Then, 1.20 tons of raw ore to 1 ton burned ore,				. . . . .	\$2 97
Labor, burning,	to 1 "	"	"	. . . . .	21.8
Wood and hauling,	to 1 "	"	"	. . . . .	07
15 per ct. coal and placing,	to 1 "	"	"	. . . . .	15
Loading on railroad cars,	to 1 "	"	"	. . . . .	12
Total cost per ton of burned ore,				. . . . . .	\$3 52.8

Formerly most of the blast-furnaces which used the sulphurous magnetite ore from Cornwall, Pennsylvania, roasted it in heaps of considerable size, and in driving off the moisture from the lump-limonites in Alabama, Wisconsin and other sections, a similar method is employed. In treating the carbonates of Ohio, both large piles and low narrow heaps are formed.

Roasting Between Closed Walls.

The method of procedure and the results possible to obtain by calcining ore within closed walls are practically the same as when roasting in open piles or ricks. In fact, the walls are simply boundaries confining the ore under treatment, and, as one side is low, or left entirely open, a partial result only is obtained, even when vent-holes are placed in the other sides. Except in isolated districts,

these partial structures are not used, most of the ores roasted being treated in open piles, or in some more or less complete roaster.

A masonry structure 26 feet long, 24 feet wide, 12 feet high at the back, and 5 feet high in front, used at Au Sable Forks, New York, for roasting magnetites so as to make them friable, is described by Professor Egleston in his paper on "The American Bloomery Process."*

One of these structures contains about 300 tons of ore, which requires 25 cords of wood for fuel, and is under treatment from 3 to 6 days.

In practice, fully as good results are obtained by forming walls of ore-lumps as by building them up with masonry.

Diligent inquiry has, however, failed to bring to notice sufficient data concerning the expense and labor of roasting either in open heaps or within closed walls, to determine any approximate figures of cost.

Few managers keep as accurate data as would be desirable, to determine closely the loss in weight, the consumption of fuel, and the labor required. In several instances above-quoted these have been given, and they are probably sufficient to determine averages.

Very little has been published upon the subject in late years, but the following is offered as being of interest in this connection.

The loss of weight during the process of calcination varies with different ores, for, whilst the black-band iron-ores of Scotland, on account of the large proportion of bituminous matter which they contain, will lose by roasting, in some cases, as much as 50 per cent. of their weight, the Welsh argillaceous ores suffer a loss of from 25 to 30 per cent., or an average of about 27 per cent. The brown hematites lose some 12 or 14 per cent., and the red hematites only about 6 per cent. of their weight. (See Greenwood's *Steel and Iron.*)

Meade, in *The Coal and Iron Industries of the United Kingdom.* asserts that "the argillaceous iron-stones of North Staffordshire lose in weight by calcination from 30 to 36 per cent. The black-band ores lose from 50 to 60 per cent., or even more."

In Alexander's report upon the manufacture of iron in Maryland —1840—the loss in weight by roasting is given at from 25 to 40 per cent. for carbonate-ores.

Crookes and Röhrig give the following information:

"Magnetic iron-ores lose from 3 to 6 per cent. of hygroscopic

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* *Transactions*, vol. viii., page 517.

water, but their weight is again somewhat increased by the higher oxidation of the protoxide. Specular and red iron-ores lose from 3 to 5 per cent., brown iron-ores from 10 to 15 per cent., limonite from 8 to 20 per cent., and sparry iron-ores up to 40 per cent., but their weight is again somewhat increased by taking oxygen into combination. Spherosiderites lose from 18 to 30 per cent., and black-band frequently above 40 per cent.

"Upon laying out the roasted ores in the air they again absorb water in different quantities, according to their state of aggregation. Dusty and clayey ores absorb about 6 per cent. They are, therefore, preferably kept under shelter. Calcareous ores when roasted contain caustic lime, which disintegrates by absorption of water, transforming the ore into a pulverized condition. Therefore, they must also be kept under shelter."

Roasting in Kilns.

Illustrations of various types of ore-roasting structures are given in works upon metallurgy, their general character being of masonry with bosh and shaft.

In some treatises, these structures are divided into those operating without grates and those having grates. An examination of these authorities offers but little that is worthy of being copied, so far as the kilns using solid fuel are concerned.

In the Hartz, masonry structures are sometimes used resembling a low stone blast-furnace stack, the internal section having a bosh and a straight in-wall; and arches are formed in the masonry for discharge-openings, similar to tuyere-arches in blast-furnaces.

In roasting in the kilns, 6.7 cubic feet of small charcoal and 13.3 bundles of brush-wood are used for 21 cubic feet of siliceous red iron-ore, and 5 feet of charcoal and 8 pieces of brush-wood for 21 cubic feet of calcareous ore. Two workmen roast daily about 285 cubic feet, and are paid 6 cents per 21 cubic feet. When roasting brown and clay iron-stones the production is increased three-eighths, and the expense for roasting 6 cents for 21 cubic feet.

In Wales, long masonry-kilns lined with fire-brick were constructed; a transverse section being a wedge 9 feet wide at top, 2 feet wide at bottom, and 18 feet high; the ore being withdrawn at the bottom through suitable openings, and draught being supplied by small holes.

Crookes and Röhrig state that such a kiln, at Dowlais, had about 70 tons capacity, and calcined 146 tons weekly, so that the average

time of burning the charge was about three days and a half. The consumption of small coal was at the rate of 1 cwt. per ton of ore, whereas in calcining in open heaps 2 cwt. of small and ½ cwt. of large coal were required to do the same amount of work.

In kilns with grates at Gleiwitz and Königshütte (Silesia) 100 pounds of ore, losing in weight 28 per cent., consume 0.13 cubic feet of small coal; one charge of ore consists of 75 cwt. and one charge of fuel of 10½ cubic feet.

At Vordenberg one charge of ore consists of 78 cwt. and a charge of fuel of from 31 to 34 cubic feet of charcoal. From three to six charges pass the furnace in fourteen hours, according to the nature of the ore, whilst during this time the grate is three times opened. Besides these furnaces, others are used in Styria of the shape of a four-sided truncated pyramid, and from 8 to 12 feet high; they are 5 feet long at the top, and from 3½ to 4 feet on the base. They consume 3 or 4 pounds of small coal for roasting 1 cwt. of spathic iron-ore, which loses in weight 19 or 20 per cent.

The average loss of weight of Welsh argillaceous ores when calcined is given at 27 per cent.; of black-band from 40 to 60 per cent.; of red hematite about 6 per cent., and of Cornish, Devonian, and similar brown hematites from 12 to 14 per cent.

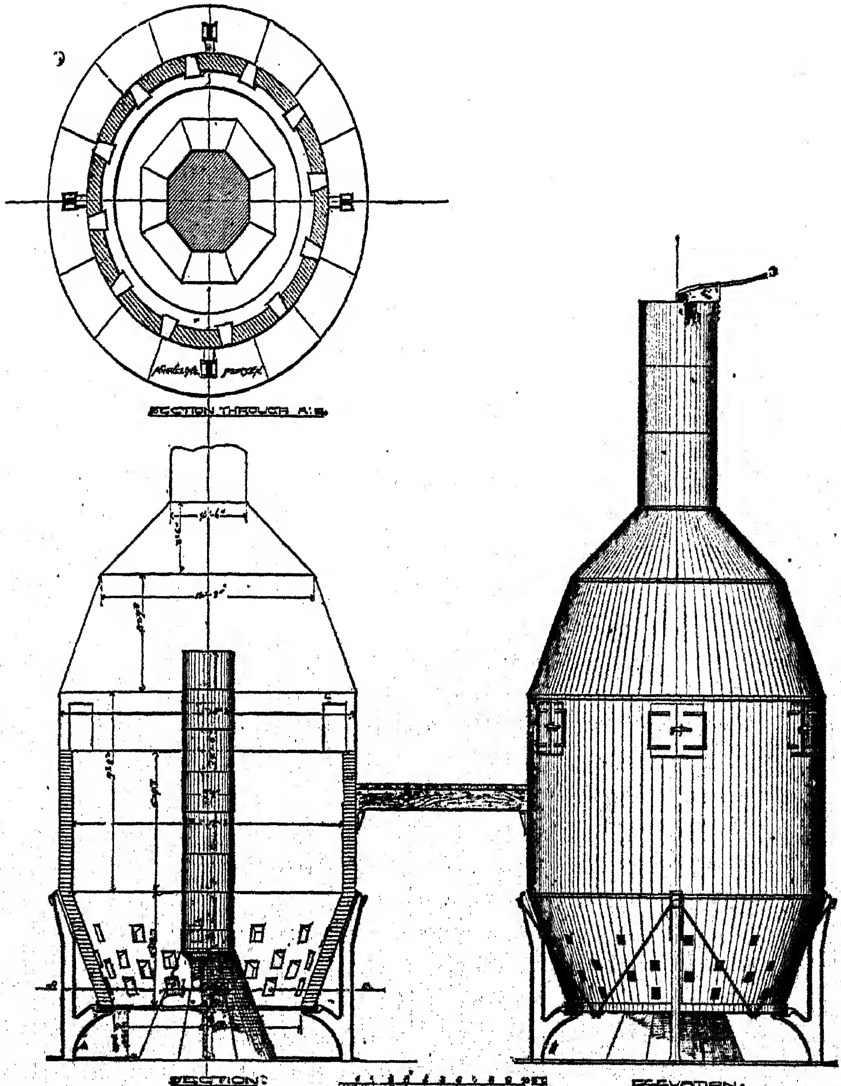
At Seraing (Belgium) 200 cwt. of ore was roasted in 24 hours, at a consumption of 72 cubic feet of coal and the same quantity of small coal.

At some French iron-works from 300 to 400 cwt. of ore is roasted in 24 hours, consuming from 4½ to 5½ pounds of coal per cwt.

A Styrian roaster to operate with wood is illustrated in Osborn's *Metallurgy*, which consists of a series of circular iron plates or rings, surrounding a central draught-chamber, the latter perforated to admit air to the mass. The horizontal spaces between the plates furnish additional air-openings at the periphery, and give access for working the ore with bars. This is rather an ore-cage than a roasting-kiln. A steam-pipe is also shown as surrounding the base for use with sulphuret ores.

The kiln which seems to meet with most general favor is known as the Gjers calcining furnace, in the Cleveland district, England. These have a bosh and shell of sheet-iron supported from a mantel resting on columns or brackets and are lined with brick. A cone of masonry covered with iron plates is placed at the bottom, and the

PLATE I.



ORE-ROASTER AT NORWAY FURNACE, BECHTELSVILLE, PA.

furnaces are often provided with iron hoods and chimneys. American modifications of these are shown by Plates I, II, III, IV, V.

In the larger kilns in the Cleveland districts, the consumption of fuel is given at 4 per cent. of the weight of ore.

The Gjers kilns are used to a considerable extent in the United States, probably more so near the Cornwall ore-hills in Pennsylvania than in any other single locality, over 90 of these structures being connected with the furnaces which receive all or a part of their ore-supplies from the Cornwall ore-hills, the size varying from 10 to 22 feet diameter at bosh, and the height from 12 to 20 feet. They are lined with red or fire-brick, and a number are provided with hoods and chimneys for withdrawing the vapors. In some cases, when a number of roasters are in a nest, a bustle-pipe surrounding each kiln is connected with a draught-stack common to all.

The kilns roast each from 10 to 50 tons of Cornwall ore per day, depending upon their size and the proportion of lump-ore charged; the ore being under treatment from 2 to 10 days.

The amount of fuel consumed in roasting one ton of ore is given as varying from 50 to 100 pounds, and the cost varies from 20 to 75 cents delivered into the furnace-charging buggies. The average, we believe, will approximate 30 cents per ton, 12 cents being for fuel and 18 cents for labor.

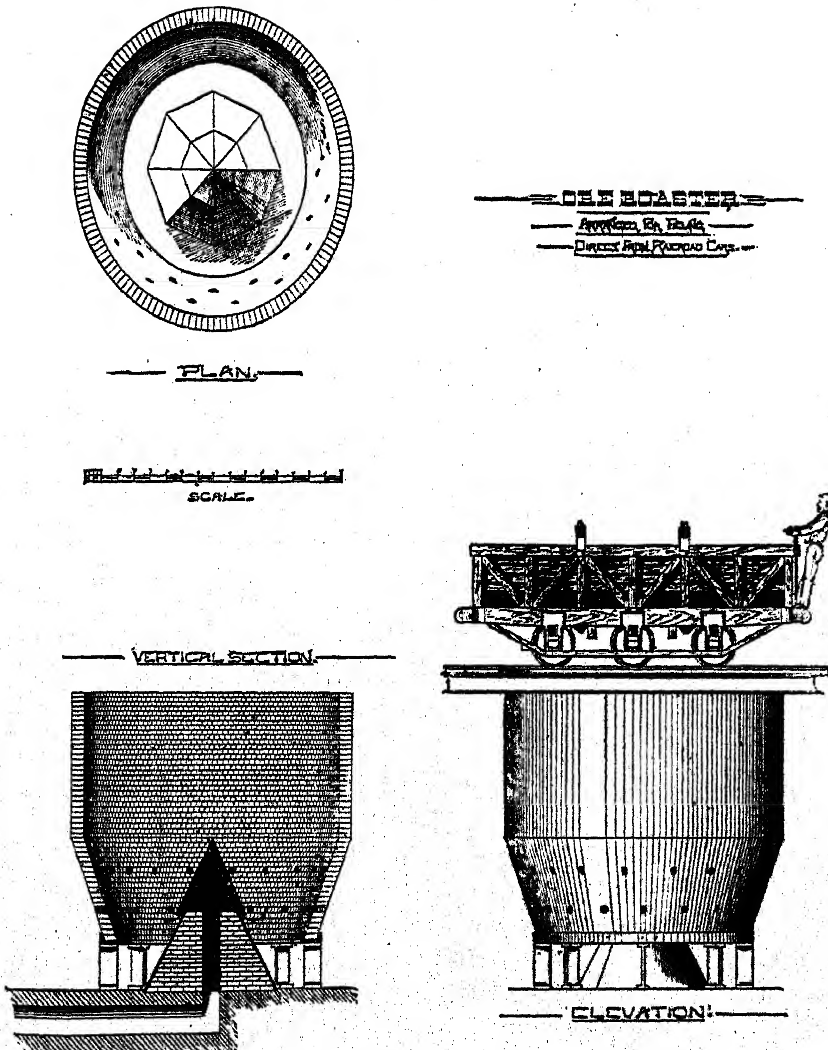
These figures were obtained from special reports made to the writer of the operation of Gjer's roasters. One report was below 20 cents, owing to a misconception of the exact query made.

The manager who reported the cost at 75 cents, mixes the ores used in the furnace before roasting them, and this outlay includes wheeling the ore in barrows from various bins to the crusher, and the expense of crushing it. Where the Grittinger kilns are used, the labor per ton of ore amounts to about 10 cents.

The Gjers kiln, as introduced into this country, had been subjected to many modifications; and while we may not refer to all, it is proposed to give such facts as will be of benefit and direct to further investigations. This type of roaster was first introduced into this country at the North Lebanon Furnaces, Pennsylvania, by the late Hon. G. Dawson Coleman, who brought the necessary drawings home with him from Europe, and expended a considerable sum in experiment and construction. The original roaster is still in use, and can readily be distinguished from those built at later dates.

Plate I shows an elevation and vertical and horizontal sections of roasters constructed at Norway Furnace, Bechtelsville, Pa., in

PLATE II.


ORE ROASTER
DIRECT FROM RAILROAD CARS.
PLAN.
SCALE.
VERTICAL SECTION.
ELEVATION.

1883. The casing of each roaster is supported by four main brackets or legs, on which both the bottom ring-plate and the bosh rest. A lining of red brick laid in clay is placed within the casing up to a level with the charging-doors, of which there are six. This lining has walled into it a series of poke-holes made with cast-iron frames. The roaster is covered with a hood of wrought-iron, and also has a wrought-iron draught-stack controlled by a damper. A solid base of masonry, octagonal in plan and conical in shape, covered with cast-iron plates, supports a boiler-iron cylinder, 3 feet in diameter, which is placed in the kiln with a view of securing a greater regularity in heating the ore and less liability of clinkering. Cast-iron plates surround the base of the kiln to facilitate shoveling the ore. The bottom ring-plate, to which the shell is riveted and which sustains the lining, is supported by the lower arm of the four main brackets, and also by tension-rods carried by stirrups on the upper arm of the brackets.

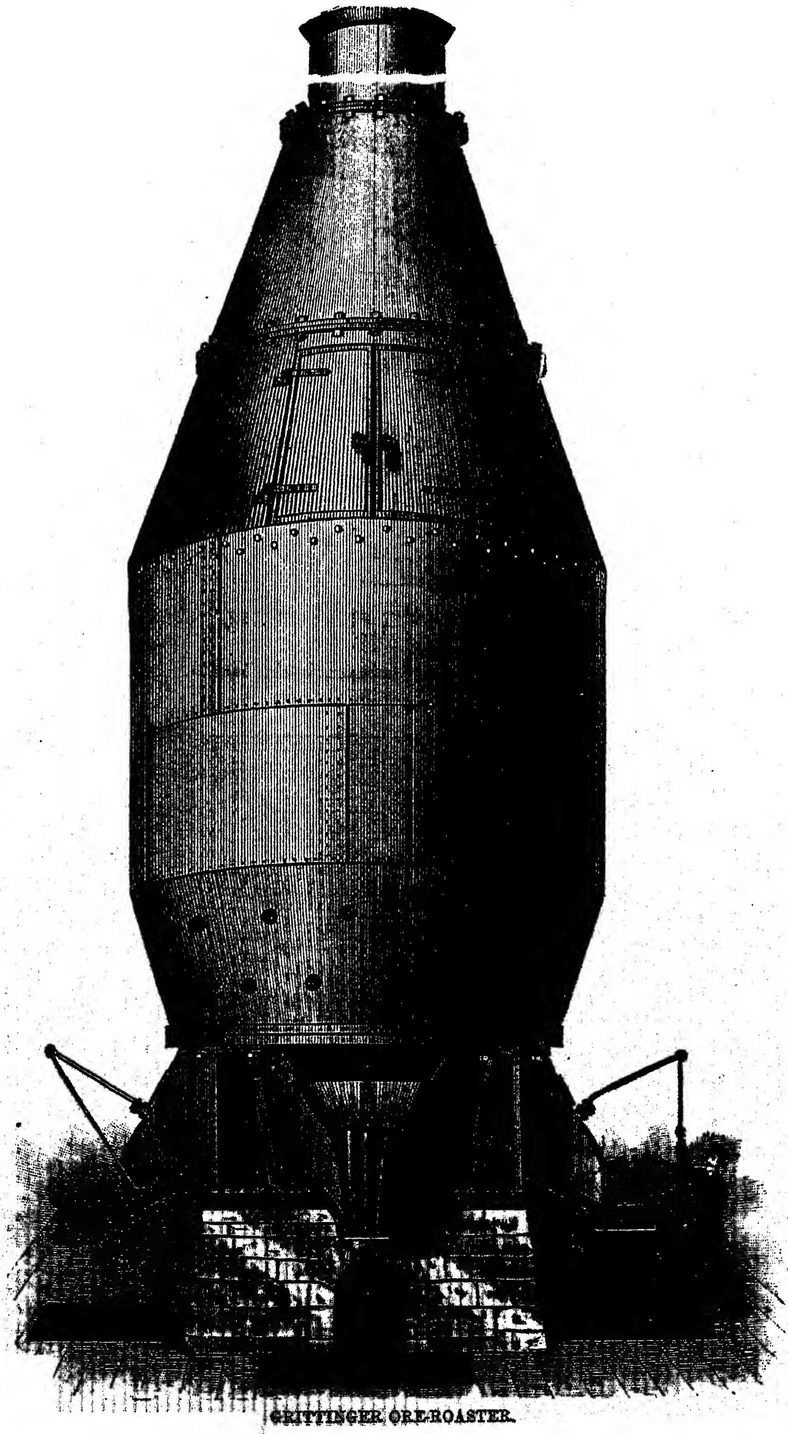
The castings required for the roaster are the main brackets, cone-plates, poke-hole frames, bottom ring, small brackets, washers, etc., and aggregate in weight for one roaster about 15,000 pounds. The shoveling-plates of one roaster weigh about 6,000 pounds. The boiler-iron for shell, cone, and draught-stack for one roaster weighs about 16,000 pounds, and the central cylinder adds to this about 1,800 pounds. In addition to the above, there will be required for each roaster 700 pounds of bolts, 11,000 red brick, 1½ tons clay, 10 cubic yards of masonry, and necessary excavation and grading.

The view of these roasters is given as one of the later constructions of this particular type. They are often constructed without any hood or cover above the charging-level. Most of them heretofore built have had the bottom ring sustained upon a series of short cast-iron columns. The central cylinder also is not in general use, the bottom cone being ordinarily continued to an apex, and sometimes made to inclose air-flues. In many cases the poke-holes are simply circular openings, cut in the shell and extended through the lining.

Plate II exhibits an elevation and section of a roaster, supported on columns and arranged to be filled directly from railway-cars which pass over the top. These roasters have perforations in the shell and lining which serve as poke-holes.

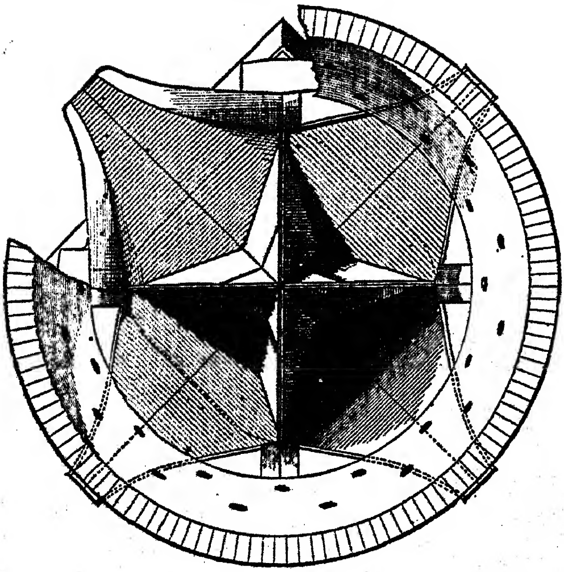
At the Colebrooke Furnaces, Lebanon, Pennsylvania, there are sixteen roasters arranged as shown on Plate II; and the height of supporting columns is varied so as to test which is best suited for treating the Cornwall ores. These kilns are 17 feet diameter at

PLATE III.

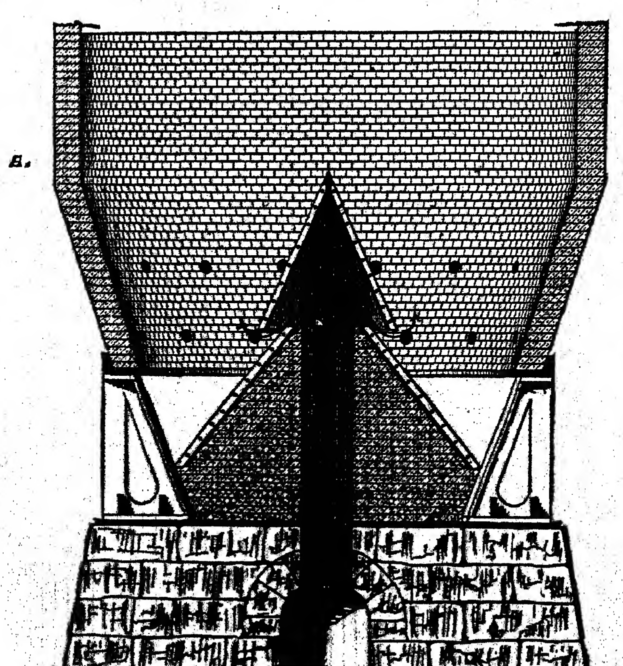


GRITTINGER ORE-ROASTER.

PLATE IV.



GRITTINGER ORE ROASTER
PATENTED
JUNE 14TH 1881.



bosh, and 15½ feet, 17 feet and 18½ feet high. The material required for this form of roaster closely approximates what is demanded for one of similar size of the pattern shown on Plate I less the cone and chimney.

Plates III and IV are illustrations of the Grittinger Ore Kiln. The former is an elevation showing the roaster surmounted by a cast-iron hood and chimney, the chimney being cut off so as not to extend beyond the size of the page. The method of discharging the kiln is also exhibited. Plate IV shows a vertical section of the roaster without a hood, and a top view looking down upon the central star-shaped cone, a portion of the shell and lining of the kiln being removed so as to show one of the chutes.

It is not necessary that the hood and chimneys be added, but where sulphurous ores are treated they are very advantageous in carrying off the sulphur-fumes. By preference, the cones and chimneys are made of cast-iron, wrought-iron deteriorating too rapidly.

The peculiarity of these kilns is in the lower portion. A series of column-brackets support a mantel carrying the shell of the kiln, and to these brackets are secured the ore-chutes and inclined bottom plates. In the centre of the kiln there is erected a cone, star-shaped in section, the points of the star abutting against the column-brackets; the spaces between the points or ridges, forming chutes of constantly decreasing incline and dividing the area of the kiln into practically uniform sections, thus encouraging a regular division of the ore to the outside shoots. A large flue passes up within the star-shaped cone and supplies ample air for combustion in the centre of the kiln, as shown by arrows in the vertical section, Plate IV.

By erecting the kiln on a masonry base and providing pivoted grates, controlled by levers, to the outside chutes, a minimum amount of labor is required to discharge the ore. The ore and fuel (the latter generally culm, slack or braize) are charged at the top in approximate layers, and ordinarily no additional labor is required, except to raise the pivoted gate when filling a charging-barrow. Should there be any sign of unequal roasting, bars can be inserted in the openings in the shell, which also supply air for combustion to the outer portion.

There are twenty of these roasting kilns in use at the Bird Coleman furnaces, and six at the North Cornwall furnace, Cornwall, Lebanon county, Pa.

The following is a memorandum of the material required for the

construction of a Grittinger kiln, 15 feet diameter, which has been furnished us by Mr. H. C. Grittinger of Cornwall, Pa., the patentee.

20 perches stone masonry in base.

10,500 red bricks in base and lining of casing.

Cast-iron base:

	Pounds.
4 columns,	5600
4 segments of mantel,	4000
24 cone or chute-plates,	9000
1 base plate,	2400
4 cast-iron shafts for shoots,	200
	21,200

Eight plate-iron sides and braces for chutes ($\frac{1}{4}''$), 1600 pounds. Bolts, bar-iron, and blacksmith work. Casing 12 feet high, 15 feet diameter at top and at bosh, and 12 feet diameter at bottom, made of 10-lb. plate-iron weighing 6500 pounds. This does not include hood or chimney.

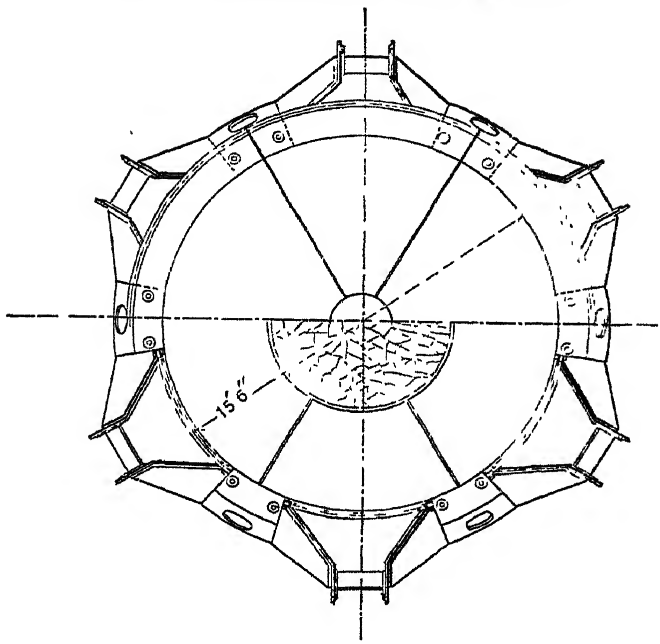
A kiln 15 feet in diameter, and of the proportions shown in Plate III, will hold about 125 tons of Cornwall ore and roast from 18 to 25 tons per day, dependent upon the amount of fine ore. The Cornwall ore, as used, is about one-half fine, and one half lump, containing about 3 per cent. of sulphur.

The consumption of fuel per ton of roasted ore is from 85 to 95 pounds of "buckwheat" anthracite coal, and the labor will average throughout the year not more than 10 cents per ton of ore roasted.

This kiln is not claimed to be a complete desulphurizer, like the gas-roasting furnaces, but it is the result of extended practical experience, and the various improvements embodied in it are believed to permit better results than any other form of roaster in which the solid fluid is mixed with the ore, driving off all the sulphur which can be expelled by the simple application of heat.

The largest roasters of the Gjers form are located at Burden Station, New York, to treat the carbonate ores from the neighboring mines of the Hudson River Ore and Iron Company. These kilns, which are illustrated in Plate V, are 24 feet in diameter and 60 feet in height. Each is constructed with a wrought-iron shell resting upon a heavy cast-iron mantel, which is supported on six cast-iron columns 10 feet 3 inches high. The space within the columns is built up of masonry to form a cone which is covered by cast-iron plates connecting with chutes. The shell is lined with brick, so that the diameter at the mantle is 17 feet 10 inches. From this point

SECTION ABOVE MANTLE.



SECTION BELOW MANTLE.

Ore-Roasting Kiln

HUDSON RIVER ORE & IRON CO.

BURDEN STATION, N. Y.

SCALE, 1–100.

pled and assayed, and found to contain 143 ounces of gold to the ton. This mixture was then amalgamated in an iron vessel without chemicals with clean mercury, and by this method 36 ounces, or 25 per cent., were extracted and 107 ounces were left in the tails. It was then amalgamated with a neutral solution of bichloride of mercury in an iron vessel and 11 ounces, or 7.5 per cent., were extracted and 132 retained in the tails, making a total of 32.5 per cent. extracted.

Another sample was treated with mercury and an acid solution of bichloride of mercury in an iron vessel and 13 ounces, or 9 per cent., were extracted and 130 left in the tails, the acidity of the solution having produced no effect. An electric current was then passed through a sulphuric acid solution with mercury; 23 ounces, or 16 per cent., were extracted and 120 left in the tails, or 25 per cent. altogether extracted.

A fresh sample was then treated with cyanide of potassium and mercury in an iron vessel, and 62 ounces, or 43.3 per cent., were extracted while 81 ounces were left in the tails. These tails were then re-amalgamated with cyanide of potassium; two ounces were extracted and 79 left in the tails. These tails were again re-amalgamated with salt, bichloride of mercury, and mercury, and two ounces, or in all 46 per cent. were extracted and 77 ounces were left in the tails.

After repeating these experiments a number of times, the conclusion was drawn that on artificially prepared substances such as these, made by fusion, the most careful and prolonged roasting did not sufficiently destroy the combinations of the gold, or more probably the coating of oxide of iron on the gold, so as to enable the mercury to reach it even when bichloride of mercury was added with a neutral solution, and no advantage was gained by treating such an ore with bichloride of mercury, even in an acid solution; and that even with cyanide of potassium, which acted the most powerfully of all the chemicals, the amount of loss would necessarily be very large, and that it is consequently dangerous in roasting ores of gold containing sulphur and arsenic ever to allow a high temperature in the furnace. The amount of sulphur contained in the roasted ore was not determined chemically, but it was quite small, and so was also the amount of arsenic. The roasting was prolonged and very carefully done, every precaution being taken to prevent such an elevation of the temperature as would cause the ore to fritt, and every effort was made to have the processes conducted exactly as they would have been in a mill.

Sulphide of antimony free from gangue was then mixed with the pulverized arsenopyrite, and fine sponge gold added to it, and the whole fused in a crucible. It was then pulverized, roasted, and assayed, showing $516.72 to the ton. It was then treated in an iron vessel with cyanide of potassium and mercury. The tails assayed $69.27, showing that 88 per cent. of the gold had been extracted.

Another sample of the same ingredients was melted in a crucible and assayed 249.5 ounces to the ton after amalgamation. The tails contained 57.7 ounces, showing that only 76.9 per cent. of the gold had been extracted.

Pulverized iron pyrites, stibnite and gold were then fused together, carefully roasted and assayed 56 ounces to the ton. The roasted ore was then amalgamated with cyanide of potassium in an iron vessel, and 9.1 ounces were extracted. The tails were then amalgamated with bichloride of mercury and mercury in an iron vessel, and 4.8 ounces extracted, or 13.9 ounces altogether, showing an extraction of only 24.82 per cent. As a microscopic examination showed a very few exceedingly small spots of undecomposed pyrites, it was thought best to repeat the experiment. Another mixture was made which, after roasting, assayed 120 ounces to the ton. The roasting was done with the greatest care at a low temperature. After the fumes ceased to be given off, powdered charcoal was added to reduce any oxidized compounds. The excess of charcoal was burned out at as low a temperature as possible. Only 25.36 ounces were extracted, or 21.14 per cent., thus confirming the previous experiment.

Up to this time I had never been able to obtain from any of the mines a mispickel containing gold. Since the Troy meeting of the Institute I have, through the kindness of Messrs. Rothwell and Platt, obtained some. The raw ore contained 14.17 per cent. of sulphur, and 20.50 per cent. of arsenic. The roasted ore contained 0.67 per cent. of sulphur and 1.87 per cent. of arsenic. The assay of the roasted ore showed it to contain $67.88 per ton in gold, and $5.17 in silver. On treating it with cyanide of potassium and mercury in an iron vessel the tails were found to contain $14.16 of gold and $3.67 silver, so that 75 per cent. of the gold, and only 30 per cent. of the silver was obtained by this process. This treatment of the roasted ore was much more successful than with the material which had been fused, and shows the necessity of avoiding high temperatures in roasting gold ores.

It is evident that without the use of expensive chemicals under conditions artificially produced there is something which prevents the

amalgamation when arsenic, antimony, and sulphur are together in the ore. Exactly what this is I have not yet been able to ascertain, but hope at some future time to be able to announce to the Institute exactly what the conditions are, which when sulphur, antimony, and arsenic are present, prevent the gold from being attacked by the mercury; but I have little doubt that it is for the most part a coating formed during the roasting, and that the imperfection of the trials is owing to the same cause, and to the very small quantities necessarily used in the laboratory tests.

As in the Roanoke meeting of the Institute doubt was thrown on the experiments on the non-amalgamation of hardened gold, I have renewed them with great care. A neutral solution of corrosive sublimate will scarcely attack gold at all under any conditions whether hard or soft. I have repeatedly tried the experiment of placing the pieces of gold in a neutral solution and touching them with a point of iron, such as a knife-blade. The blade of the knife became invariably corroded, and amalgamation sometimes took place at the point where the iron touched the gold, but spread no further even after prolonged contact with the iron. When this same soft gold was placed in an acid solution and touched with an iron point, the amalgamation took place instantaneously. When, however, the gold which has been hardened by beating on an anvil, is subjected to even the acid solution, it amalgamates very slowly, even with prolonged contact with the salt of mercury.

Through the kindness of Tiffany & Co. I obtained samples ot pure gold and of gold alloyed with copper. These samples were first rolled until they were extremely hard and then were hammered on an anvil and were placed in contact with mercury. After a considerable time they began to amalgamate very slowly. Samples of the same gold were then annealed in an ordinary Bunsen flame, after which annealing they became perfectly black and would not amalgamate at all under any conditions, owing to the formation of an oxide of copper upon the surface of the metal which prevented contact. When, however, the original alloy and also the alloy annealed was treated in nitric acid they both amalgamated with equal readiness. It appears therefore that not only will fine gold which is hammered be prevented from amalgamation, but that the ordinary alloys of gold will also be prevented equally from amalgamation. When fine gold, as I stated in my previous researches, is hammered, it does not amalgamate; but when it is annealed, it will immediately amalgamate. This appears not to be the case with all

alloys, where there is an opportunity in the course of annealing for an oxide to be formed.

In order to reproduce the conditions in which metallic gold is found in the stamp mills, strips and pieces of gold were pounded in a perfectly clean iron mortar with a clean pestle in as nearly as possible the same conditions as they would be in an ordinary stamp mill. It was found that when the stamping was done under water and with light blows, and for only a short time while there was an evident increase in the difficulty of amalgamating, the gold did amalgamate with sufficient readiness to insure that the most of it would be caught by the mercury after prolonged contact. When, however, the blows were very heavy and the pounding continued for some time so as to flatten out the piece, prolonged contact with the mercury produced only a very slight amalgamation which did not even show the smallest trace under five minutes, and was only partial even after half an hour. Every attempt was made to make the mercury attack this gold. It was placed directly in and on it, but the quicksilver rolled over and over as if the gold had been so much sheet iron. Even when the mercury commenced to adhere to the gold it was in very minute spots which did not spread for a long time. When a piece of the same metal was treated with acid, there was a perceptible difference in the rate of amalgamation; but it was still very slow, too slow for the amalgamation of an ordinary stamp mill. When these same pieces were annealed they amalgamated immediately. The same operation was repeated on pieces pounded in a mortar without water. The amalgamation took place even more slowly than before. When the pieces were cleaned with acid they amalgamated about as slowly as the pieces treated under water which had not been cleaned. It took a much longer time to produce the adherence of the fine globules of mercury, and they propagated themselves much more slowly. In every case where a freshly broken edge came in contact with the mercury it was attacked at once, showing that a film had been formed which prevented contact. This film is slowly dissolved by acids and quickly dissipated by heat, for when they were annealed the pieces amalgamated at once. The same results were obtained when the gold was beaten on a dusty anvil.

The same experiments were tried with silver. Pieces obtained from an assay, which were consequently nearly pure, were pounded in a mortar, some with, others without water. Those in which the water was used presented a perfectly clean appearance somewhat

duller than the ordinary color of silver, and when made into a small dish and a globule of mercury placed upon it, it retained the mercury for a considerable length of time without being affected by it at all. When the mercury was placed in a vessel, and the silver dipped in it, it did not attack it all at first, but after considerable agitation and rubbing against the sides of the vessel an attachment was made on the edge. When this edge was broken the mercury attacked the fracture at once, very fine globules being disseminated all over the edge. Notwithstanding this the surface resisted the contact of the mercury for a considerable length of time, and then was only irregularly attacked. When the piece was treated in diluted sulphuric acid for some time and then cleaned and treated with mercury, it resisted in the same way, but for a shorter time. When this piece so cleaned was annealed in a Bunsen burner, the mercury attacked it instantly.

The pieces which had been pounded in the mortar without water, had a much darker appearance in patches unevenly distributed over the surface of the piece. It resisted the action of the mercury for a great length of time, but when placed in a vessel with the mercury and treated with sulphuric acid, it acted in about the same way as the piece pounded under water did before being cleaned. It would have taken a very long time to have amalgamated the whole of the piece. When the cleaned piece was, however, annealed and placed in the mercury it amalgamated like all the others instantly.

It thus appears that silver as well as gold is affected by pounding, and that under the most favorable conditions, where no foreign material is present, it will amalgamate with very great difficulty. When, however, any foreign material, as dust, or small particles of ore had been allowed to remain in the mortar or on the pestle, the amalgamation took place even more slowly than before, and in some cases after a number of hours, no perceptible effect of the mercury could be observed. That this coating is a superficial one, that amalgamation is possible where there is a freshly broken edge, and that this amalgamation on the edge will eventually extend through the whole piece, and that the pounding of the pieces is undoubtedly a source of loss in the mills, these experiments seem to settle decisively.

It is well known to silversmiths that when silver is annealed after being hardened it turns black, and that when this is placed in the pickling acid the black substance is dissolved upon the surface and it becomes perfectly white. When, however, this white coating

is brushed into, there appears below it a purple coating which is composed of the oxides of copper and of silver, and this purple coating cannot be removed except at considerable expense. A microscopic examination of the coating shows that when the pickling acid attacks the coating of oxides, it does so only superficially, leaving a porous coating, which when highly magnified shows the oxide below. As the oxides are lodged in the bottom of the lines of the scratches which are produced by the polishing, the decomposition of the light gives the appearance of a purple color. When, however, the objects are highly magnified, only the white color of the pure silver and the brown in the bottom of the depressions of the scratches are seen. It seems probable that similar oxides form upon gold-alloys and prevent the contact of the mercury.

Discussion.

R. P. Rothwell, New York City: I have been treating arsenical pyrites for some time. I have made a good many tests, covering perhaps a thousand or fifteen hundred tons of mispickel ores, treating by amalgamation in pans, and I do not find the difficulty that Dr. Egleston has suggested in roasted ores. On the contrary, I was able to get out over eighty, up even to eighty-six per cent. of the gold from roasted mispickel. If Dr. Egleston had confined his remarks to raw mispickel, I think he would have expressed about what I found to be true in treating the raw ores by amalgamation, but in the roasted ores, you can get out a very large percentage.

The percentage that can be amalgamated in raw mispickel will probably not exceed 30 to 40. The reason for this I am not able to state; but Mr. Riotte of Mathey & Riotte, of New York, who tested some of our mispickel ores, told me that he had examined it with a microscope, and that the gold in it was what you would call coarse gold, though to the naked eye the gold seemed pretty fine, yet under the glass it was comparatively coarse gold. As far as he could see with the microscope, it stopped suddenly at a certain line and beyond that he found no fine gold. Even though he pulverized it very finely in a mortar, he could find no more free gold in it. He then assayed this remaining mispickel that had not apparently any gold in it, and he found, as he told me, very uniformly about twenty dollars a ton in it, that was in the condition of what he called "combined gold." I do not know whether that is the reason that it did not amalgamate, but I know that the arsenic has something to do with it, and that this is very injurious in amalgamation by reason of

flouring the quicksilver; but when you roast these ores, even though you are unable to get out all the arsenic, there is no difficulty whatever in getting at least as perfect an amalgamation as you do from free gold-ores generally. When we extracted that percentage, the roast was made in a revolving cylinder 24 feet long, and it was not so perfect a roast as is necessary for chlorination, and yet we got that high percentage. When the ores are thoroughly roasted, although they still contain some arsenic, which you find in solution after chlorination, they will amalgamate up to a very high percentage. The average of the first eight hundred tons that I treated by chlorination gave about ninety-four and a half per cent. and it ran up to ninety-eight and even ninety-nine per cent., fire assay, that we would get out by leaching the chlorinated ore. But chlorination requires a more perfect roast than amalgamation. I see nothing, therefore, in the arsenic that interferes with chlorination, nor with amalgamation, if you roast the ores well; though you never get rid, as I say, of all the arsenic, which you find again in the solution, where it produces new complications, which the Professor has not referred to and which it is not necessary to mention.

NOTE ON THE FIRE CREEK COKE OF WEST VIRGINIA.

BY FRED. P. DEWEY. WASHINGTON, D.C.

In my paper on the porosity and specific gravity of coke, read at the Roanoke meeting, June, 1883, and published in this volume, an analysis by Dr. Henry Frœhling is reported (p. 10 of the preliminary edition of the paper, or p. 120 of this volume), as showing the composition of Fire Creek coke. This analysis was of coke made in beehive ovens at Low Moor, Va., from New River coal. Dr. Frœhling's analysis of the Fire Creek coke was as follows:

Moisture	0.260
Volatile matter	0.260
Fixed carbon	92.377
Ash	6.750
Sulphur	0.535
Phosphorus	0.0146

Both analyses are reported side by side in *The Virginias* for 1883, p. 99. By an error in copying, the Low Moor analysis was trans-

ferred to my paper, instead of the Fire Creek analysis, which I intended to quote.

THE LAW OF THE APEX.

BY R. W. RAYMOND, NEW YORK CITY.

THIS name is applied to the present mining law, as enacted in 1872 and since, to indicate its leading characteristic—in which it differs from all previous mining laws of this or any other country. The earlier act, passed in 1866, was practically the first attempt of Congress to deal with the question of mining titles upon the public domain. It was framed after nearly twenty years of acquiescence on the part of the Government in the self-constituted tribunals, officials, rules, and customs of the mining districts. In its recognition of these, and in several other particulars, the act of 1866 was open to serious criticisms. It is the purpose of this paper, not to trace the history of legislation on this subject, or show in detail what were the faults of the earlier law, but rather, by a discussion of certain aspects of the present law, to point out how great a revolution it has effected in the rights of mining locators, and to indicate some of the difficulties attending its application.

In the attempt to correct the vagueness of the act of 1866 an entirely new element was introduced into the law, bringing with it a new set of difficulties. Under the act of 1866 and the miners' customs which it followed, the lode was the thing claimed and subsequently acquired by patent. And the claim to a given number of feet on the longitudinal course of the lode was rooted in a discovery of any part of the lode in any part of the claim. ("Extensions" could in many districts—perhaps universally—be located and claimed on the strength of the discovery in the principal claim to which they referred; but this is a point not essential to the present discussion.) It was not necessary to find the outcrop or the upper edge of a lode in order to lay a valid location upon it. An explorer, sinking a shaft and intersecting a lode not already discovered and claimed by another, could claim by that discovery the number of feet along that lode which the local laws might permit (not exceeding the maximum set by the United States statute) whether his sur-

veyed surface-claim included the outcrop or not. The surface, although it might be surveyed and bought for so much per acre from the United States, was not conveyed in fee to the locator. He acquired only an easement or right to occupy this surface with shafts, adits, buildings, machinery, dumps, etc., necessary for the working of his mine. By one decision, at least, in Nevada, it was held that a patentee could exclude explorers from the surface of his claim; but this was overruled by the Supreme Court of the State on the ground that the United States statute was intended to confirm, not diminish, the rights of miners as existing before its passage. On the same ground it was held in Utah (in the Emma-Illinois case) that the right to a certain number of feet of the course of a lode "together with the right to follow such vein or lode, with its dips, angles, and variations, to any depth, although it may enter the land adjoining," was independent of the surface-lines of the location. This case was never appealed, but the decision was reversed by the United States Supreme Court in the Flagstaff case (*Flagstaff S. M. Co.* v. *Tarbet*, 8 Otto, 463), to which further reference will be made.

The act of 1872, in its third section (now section 2322 of the Revised Statutes) reads as follows:

"The locators of all mining-locations heretofore made, or which shall hereafter be made, on any mineral vein, lode, or ledge, situated on the public domain, their heirs and assigns, where no adverse claim exists on the tenth day of May, 1872, so long as they comply with the laws of the United States, and with State, Territorial, and local regulations not in conflict with the laws of the United States governing their possessory title, shall have the exclusive right of possession and enjoyment of all the surface included within the lines of their locations, and of all veins, lodes, and ledges throughout their entire depth, the top or apex of which lies inside of such surface-lines extended downward vertically, although such veins, lodes, or ledges may so far depart from a perpendicular in their course downward as to extend outside the vertical side-lines of such surface-locations. But their right of possession to such outside parts of such veins or ledges shall be confined to such portions thereof as lie between vertical planes drawn downward as above described, through the end-lines of their locations, so continued in their own direction that such planes will intersect such exterior parts of such veins or ledges. And nothing in this section shall authorize the locator or possessor of a vein or lode which extends in its downward course beyond the vertical lines of his claim, to enter upon the surface of a claim owned or possessed by another."

Section 2 of the act of 1872 (section 2320 of the Revised Statutes) makes the following provisions as to shape and size of claims:

"Mining-claims upon veins or lodes of quartz or other rock in place, bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits, heretofore located, shall be governed as to length along the vein or lode by the customs, regu-

lations, and laws in force at the date of their location. A mining-claim located after the tenth day of May, 1872, whether located by one or more persons, may equal, but shall not exceed, 1500 feet in length along the vein or lode: but no location of a mining claim shall be made until the discovery of the vein or lode within the limits of the claim located. No claim shall extend more than 300 feet on each side of the middle of the vein at the surface, nor shall any claim be limited by any mining regulation to less than 25 feet on each side of the middle of the vein at the surface, except where adverse rights existing on the tenth day of May, 1872, render such limitation necessary. The end-lines of each claim shall be parallel to each other."

Section 12 of the act of 1872 (section 2329 of the Revised Statutes) begins as follows:

"Claims usually called 'placers,' including all forms of deposit, excepting veins of quartz or other rock in place, shall be subject to entry and patent, under like circumstances and conditions, and upon similar proceedings, as are provided for vein or lode claims."

The same section of the act of 1872 (section 2330 of the Revised Statutes) fixes the maximum size of a placer-claim at 160 acres for any one person or association, and section 11 of the act (section 2333 of the Revised Statutes) provides that:

"Where the same person, association, or corporation is in possession of a placer-claim and also a vein or lode included within the boundaries thereof, application shall be made for a patent for the placer-claim, with the statement that it includes such vein or lode, and in such case a patent shall issue for the placer-claim . . . . including such vein or lode, upon the payment of five dollars per acre for such vein or lode-claims and 25 feet of surface on each side thereof. The remainder of the placer-claim, or any placer-claim not embracing any vein or lode-claim, shall be paid for at the rate of two dollars and fifty cents per acre, together with all costs of proceedings; and where a vein or lode, such as is described in section 2320,* is known to exist within the boundaries of a placer-claim, an application for a patent for such placer-claim, which does not include an application for the vein or lode-claim, shall be construed as a conclusive declaration that the claimant of the placer-claim has no right of possession of the vein or lode-claim; but where the existence of a vein or lode in a placer-claim is not known, a patent for the placer-claim shall convey all valuable mineral and other deposits within the boundaries thereof."

These extracts from the law will suffice to bring before us the points to be discussed in the present paper. A careful examination of them will show the following facts:

1. There is no difference of status between locators and patentees *of lodes* as to the extent of their rights of possession and enjoyment. Other sections than those quoted above show the difference to be one

* That is, a vein or lode "of quartz or other rock in place, bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits." R. W. R.

of tenure only—the mere possessory owner being obliged to maintain his title by annual work and by obedience to local regulations, and being liable to attacks upon his title against which the patentee is expressly protected, after the period of his public advertisement has passed, and his patent has been granted. But there is this important difference between a locator and a patentee *of placer-claims*, that the former does not own by virtue of his placer-*claim* any lodes that may be discovered within it, while the latter, by virtue of his placer *patent*, has a complete title to all lodes within the placer-claim, which were not known to exist there when the patent was granted, or probably, even, when the application for patent was made. But this right does not extend, as it might do under a lode-location and patent, to "exterior parts" of such lodes.

2. The title conferred by a lode-patent comprises the usual common-law right to the surface and all that is upon it or beneath it—with one addition and one corresponding reservation. The addition is the right to follow certain veins under certain conditions and within certain limits, into adjoining ground; the reservation is its counterpart, namely, the liability to be intruded upon, through the exercise of the same right by the adjoining owner. That is to say, all parts of lodes within the claim or patent, which have their top or apex outside of it belong to the locators whose claims include such top or apex; and they have also the right to come and get their property—without which right, the mere ownership of it would be a barren pleasure.* These extra-lateral mining rights are often spoken of as something different in character and origin from the common-law right. But, as I have elsewhere shown,† this is not the case.

* "The property in minerals is not necessarily accompanied by the right to work for them." Collier's *Treatise on the Law Relating to Mines*, Am. ed, Philadelphia, 1853, section 3, p. 14.

† In Lalor's *Cyclopædia of Political Science*, article "Mines;" also in letters to the Public Land Commission, published in the *Eng. and Min. Journal*, November 22d to December 20th, 1879, and in the Report of the Public Lands Commission to the Senate and House of Representatives (Washington: Government Printing Office, 1880) from which I quote the following passages (pp. 643 *et seq.*):

"The mineral right, however [under the common law], although it accompanies the surface-ownership, is separable by the act of the owner. A farmer in New Jersey may lease or sell the right to mine and carry away all the iron ore in his farm, with the privileges of entry and use of the surface necessary to mining operations, retaining his title in all other respects unimpaired; or he may thus dispose of the right to a single bed or vein of ore, retaining all others. A farmer in Pennsylvania may in like manner lease or sell all his coal-rights, or the right to one or more specified seams of coal, reserving to himself, undiminished, whatever is not thus transferred.

We have simply to deal with the fact that the United States, as sole owner of the public domain, has chosen to permit its occupation and exploration, and to sell it to citizens on certain terms and conditions. However whimsical or unprecedented these terms may be, or whatever hardship they may involve in special cases, there is no appeal from them to any supposed "principles" of mining law.

3. The old right of discovery, which was the basis of the miners' title down to 1872, has dwindled under the present law to a nominal importance. It is true that a "discovery of the lode" within the claim is made a pre-requisite to location. But the right to follow the lode in depth beyond the side-lines of the claim depends no longer on having discovered it, but on having included its top or apex within the surface-survey. Even to that portion of the lode actually discovered, which lies within the surface-boundaries, the right of the locator is not secure, unless his location includes the apex; for, if he have it not, his adjoining neighbor may have it, in which case the neighbor will have the right to follow the lode into the land adjoining. And, on the other hand, the original discovery may turn out to have been valueless; nevertheless, the location based on such a poor or barren seam will carry with it the right to all rich veins, which may have a top or apex in the same ground, though the actual discovery of such seams be made elsewhere, even at a prior date.*

A party owning the adjacent farms may grant the mineral right to a given deposit of coal, ore, or other mineral upon one of them, with the right to follow and mine in the other that deposit only. All these and many other varieties of grants actually occur in our Eastern States; and the rights thus conferred, as defined by the agreements creating them, are independent of surface-ownership, although in their origin they rest upon the principle that the owner of the surface owns also the minerals beneath it.

"The Government occupies precisely this position towards the public domain. It can do what it likes with its own. There is no 'miners' right,' created by the discovery of valuable mineral in any part of that domain, except what the Government chooses to create by its own voluntary acts. By such acts it is bound, as an individual would be, neither more nor less. It is as free as any individual would be to dispose, as it may see fit, of any rights not already conveyed away; to change its policy at any time; to lease or sell on new conditions, or to decline to lease or sell at all. This elementary statement seems to be required to correct a popular impression that the principles of the law of mines are different in different parts of our country, and that there is some mysterious obstacle in this difference to the introduction of a uniform system."

* I am aware that it was held, in the United States Circuit Court of Colorado, in *Vanzandt* v. *Argentine Mining Company* (Copp's *United States Mineral Lands*, p. 410), that a location along the line of the top, apex, or outcrop of the vein, cannot

4. What I have called the extra-lateral mining right of the locator is granted in a peculiar form. There is first a sweeping grant of "the exclusive right of possession and enjoyment" of "all veins, lodes and ledges throughout their entire depth, the top or apex of which lies inside of such surface-lines [the surface-lines of his location] extended downward vertically, although such veins, lodes or ledges may so far depart from a perpendicular in their course downward as to extend outside the vertical side lines of such surface-locations." This phraseology has the merit of clearly conveying the meaning intended, though descriptive geometry and the English language suffer somewhat in the operation. "Vertical side-lines" of surface-locations and horizontal lines, "extended downward vertically," are perhaps fit accompaniments to the singular "top or apex" of the plural "veins, lodes, or ledges." But the goal is reached, though the vehicle is damaged. In these particulars everybody knows what the law means; because everybody assumes that it means something, and everybody sees that it cannot mean anything else. This sweeping grant is followed by the limitation: "But their right of possession to such outside parts of such veins or ledges shall be confined to such portions thereof as lie between vertical planes drawn downward, as above described, through the end-lines of their locations, so continued in their own direction that such planes will intersect such exterior parts of such veins or ledges." It will be seen that nothing limits the rights of the locator, outside of his location, to "*all* veins," etc., having their top or apex in or under his surface-claim, except the vertical planes drawn through his surface end-lines.

5. That the terms "vein," "lode" and "ledge," are synonymous in the statute appears from the manner in which they are employed. Thus, in section 2322, above quoted, we have the phrases: "vein, lode, or ledge;" "veins, lodes and ledges;" "veins or ledges;" "vein or lode"—all apparently referring to the same thing. It is evident that the omission of "lode" in one place, and of "ledge" in another, from the comprehensive triple phrase, is not intended to

prevail against a senior location on the dip. But, while this is in accordance with the spirit of the old miners' customs, and grants a praiseworthy recognition to the merits of the prior locator, it is squarely against the letter of the statute, which can scarcely be evaded in such a way. The court, in the above case, gave no reason for its ruling, and, indeed, seemed scarcely to be conscious of its revolutionary character. The law is plain and uncompromising. Whoever has the apex takes the vein, *quoad* the section between the end-lines of his claim. There is no reservation whatever in favor of prior locators.

make it less comprehensive. Nor does section 2329, which includes under "placers" "all forms of deposit, excepting veins of quartz or other rock in place," mean that "lodes" or "ledges" are placers, whatever it may mean as to irregular masses or impregnations. I should not deem it necessary to dwell on this point, but that in one case, at least, an important ruling has been based upon the supposed distinction between veins and lodes.*

It appears, then, that the miner's rights are dependent upon the lode, the top or apex, the downward course of the lode, and the end-lines of the location. Yet the statute gives no light upon the all-important questions, What is a lode? What is the top or apex of a lode? How is the downward course of a lode to be determined? while, as to the direction in which the end-lines are to be drawn, it prescribes only that they must be parallel.†

The typical or normal case, evidently contemplated by the statute, is that of a well-defined lode, without variation in dip or course, having a horizontal outcrop, and a location in the form of a rectangle, covering this outcrop throughout the entire length of the location, and terminating in end-lines which cross the course of the lode at right angles. All other "veins, lodes or ledges," having a top or apex in the same ground, are conceived to be parallel in course and dip with the lode first discovered, which is the foundation of the location. If all mining properties presented this beautiful simplicity of structure, and all mining locators exhibited a corresponding simplicity of purpose, the application of the law would be easy. But the *naiveté* of the statute fares badly between the freaks of nature and the tricks of man. The decisions of the courts have done something to clarify, and not a little to complicate, the situation. On the whole, they have, perhaps, improved it; and by the time the various questions involved shall have been finally passed upon by the Supreme Court, we shall have found out whether the statute can be fairly applied in practice, or not. My own impression is that to construe the law is not difficult; but that its strict construction may make it odious. So long as local tribunals try to

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* In the case of the *Colorado Central* (*G. W. Hall et al.*) v. *Equator Mining and Smelting Company* (Georgetown, Colorado), tried first before Judge Hallett, February 3d, 1879. At the second trial, in July, 1879, Judge Miller took a different view. This case will be more fully discussed further on.

† Even this provision "is merely directory, and no consequence is attached to a deviation from its direction."—*Eureka Cons. M. Co.* v. *Richmond Cons. M. Co.* Field, Sawyer and Hillyer, JJ., 4 Sawyer, 311.

accommodate it to local needs or prejudices, it will remain vague—and popular with the litigating classes which form so large a part of the mining communities. If its enforcement brought hardship to them, we might hope for their assent (hitherto withheld) to its salutary amendment.

I propose to consider, in their order, the inherent difficulties of applying the law, connected with the lode, the top or apex. the course downward and the end-lines.

I. The Lode.

As already observed, the terms, "vein," "lode," and "ledge," employed in the statute, are intended to be synonymous. I shall, therefore, use the word "lode," instead of either of the others, or all three together. Of course, the question, What is a lode? arose early in litigations under the law. It had less importance under the old miners' customs, though even then it occasionally became the question upon which the possessory title to property depended. I think it fair to say, however, that, prior to 1866, courts, juries and parties assumed that any ore-bearing zone of rock in place was a lode.* The contest was usually between two claimants, one of whom maintained that the other was working on *his* lode, which the other denied the identity of the deposit as disclosed in the two sets of workings. The conclusive proof of identity was the continuous occurrence of ore, connecting the two. Against such proof, if unimpeached, resistance was impossible. In the absence of such proof, it was not easy to get identity admitted on mere geological or mathematical grounds.

* It was not even necessary that the rock claimed should be in place. Thus, in *Brown* v. *Quartz Mining Co.* (15 Cal., 152), it was held that where quartz rock was broken and parted from the original vein, but it was found by the jury as a fact that it was a portion of the same quartz lode or claim, it was immaterial whether it was upon the surface or beneath it, or in what condition the quartz was; the first locator of the lode was entitled to it. He is not confined simply to the solid quartz actually embodied in the bed-rock, but is entitled to the loose quartz rock and decomposed material, which were once a part of the lode and are now detached, so far as the general formation of the ledge can be traced. The right of the quartz-miner comes from his appropriation, and whenever his claim is defined, there is no reason in the nature of things why the appropriation may not as well take effect upon quartz in a decomposed state as any other sort, or why the condition to which natural causes may have reduced the rock should give character to the title of the locator. Such quartz rock, therefore, would be included under the general term of a "quartz ledge." I quote the foregoing from the digest of this decision given by Blanchard and Weeks (*The Law of Mines, Minerals, and Mining Water Rights*, San Francisco, 1877, p. 21).

Under the law of 1866, however, and still more under the law of 1872—the one now in force—the nature of the deposit, as a lode or not a lode, became matter for keen dispute; since, if it were not a lode, even continuity of ore would not justify the locator in following it beyond his location, while, if it were a lode, the local absence of ore in places would not destroy that right.

The view held by the General Land Office at Washington on this subject, has been liberal from the beginning. Passing over some of the earlier rulings, made by Commissioner Joseph S. Wilson, whose experience in agricultural land-law was wide, but whose notions on the subject of mining were somewhat hazy, I quote the following clear and sensible decisions of Commissioner Willis Drummond, which are remarkable as stating in advance the ground to which the courts subsequently came.*

DEPARTMENT OF THE INTERIOR, GENERAL LAND OFFICE,
WASHINGTON, D. C., July 20th, 1871.

HON. THOMAS BOLES, Dardenelles, Arkansas.

SIR: In reply to your inquiry of the 11th instant, I have to state that the term, "rock in place," as used in the mining acts of Congress, has always received the most liberal construction that the language will admit of, and every class of claims, that, either according to scientific accuracy or popular usage, can be classed and applied for as a "vein or lode," may be patented under this law.

The plain object of the law is to dispose of the mineral lands of the United States for money-value, and it is a matter of indifference to the government, whether the metal occurs in the form of a true or false vein.

It may be observed, as an important point, that no proof is required to establish the vein-formation of the deposit. The law requires the Surveyor-General to certify "to the character of the vein exposed;" but this is understood to mean that the certificate should show whether the vein exposed contains gold, silver, cinnabar, or copper.

Very respectfully,
WILLIS DRUMMOND, Commissioner.

It will be remembered that this refers to the law of 1866.

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* In the famous Eureka case (4 Sawyer, 311), these decisions of the Land Office were, if I remember correctly, not quoted either by the counsel or the court. Although "Department law" is not binding upon courts, yet it seems to me that these decisions not only carry the force of their own reasoning, but are directly in point as the acts of the authorized representative of the government, fixing the sense in which it, as one party to the sale of mineral property, construed the terms describing the property. That is to say, the government, through its executive agent, declares to the miner, with regard to a certain deposit, "I sell you this thing as a lode. You will not be allowed to apply for it as anything else." After that, does not the purchaser acquire with the deposit all the rights and privileges attached by the government to a lode? This consideration, however, was not required to bring the court, in the Eureka case, to a correct decision.

"DEPARTMENT OF THE INTERIOR, GENERAL LAND OFFICE,
"WASHINGTON, D C, February 12th, 1872.

"THOMAS N. STODDARD, ESQ, SONORA, CALIFORNIA.

"SIR: . . . . If it was intended to ask if the auriferous cement-claims, found in what are sometimes called ancient river-beds, and usually worked by the hydraulic process, properly come within the signification of the term 'rock in place,' as used in the second section of the mining statute of July 26th, 1866, then the answer must undoubtedly be in the negative; several claims of that character having already been patented under the placer mining law of July 9th, 1870, they fully coming under the meaning of the term 'placer' as defined in said act. . . .

"Very respectfully, WILLIS DRUMMOND,
"Commissioner"

The placer mining law here referred to, is now substantially contained in sections 2329, 2330, 2332, 2335, 2340, and 2344 of the Revised Statutes. In 1868, there being no U. S. statute covering this class of mines, Mr. Wilson, then Commissioner of the General Land Office, made a startling decision, including placer, gravel and cement mines under the act of 1866. So far as I know, there was no patent issued in accordance with this ruling; and Mr. Wilson's successor appears to have ignored it. The passage of the placer-mining law removed all temptation to claim such deposits as lodes, the patentable placer claim being both larger and cheaper per acre than the lode-claim.*

The following is taken from a general circular of instructions, issued to Surveyors-General, and Registers, and Receivers:

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* In the report of 1869 (for the year 1868) of the U. S. Commissioner of Mining Statistics, the following language is used (p 218, foot-note) concerning the strange ruling of Commissioner Wilson:

"A recent decision of the Commissioner of the General Land Office includes placer, gravel and cement mines under the operation of section 2 The words of the Chairman of the Committee on Mines and Mining, in reporting the bill to the Senate, May 28th, 1866, were: '*By this bill it is only proposed to dispose of the vein-mines. . . .* It is not proposed to interfere with, or lay any tax upon, *the miners engaged in working the placer-mines*' The words of the law are, 'vein or lode of quartz or other rock in place, bearing gold, silver, cinnabar or copper' There is no possible construction of these words which will include placer mines, or alluvial deposits or beds. The Commissioner argues that there are different kinds of veins, and that it is difficult to decide how a vein was formed—all of which does not touch the case. Amid all the discussions of geologists about vein-formation, the distinction between all veins and alluvial deposits has never been disturbed. It is found in the earliest laws, and is perfectly comprehended by the ordinary miner. The United States law of 1866 cannot be applied to mines of the latter class; it was an experiment, applied only to 'quartz-mining;' and the attempt of the land office to extend it over placers, before a single quartz-mine has received a patent under it, only tends to bring the whole law into contempt.

"DEPARTMENT OF THE INTERIOR, GENERAL LAND OFFICE,
"WASHINGTON, D. C., July 15th, 1873."

"GENTLEMEN: . . . . It will be observed that the mineral-producing lands are divided into two classes: the one class embraces lands where the mineral matter is within 'rock in place,' or, geologically speaking, *in situ;* and the second includes placers and all forms of deposits, excepting those in 'rock in place.' In this connection, I deem it a matter of importance to give the construction this office places upon the expression, 'vein or lode of quartz or other rock in place,' to prevent mistakes in locating the two classes of mines referred to, thereby saving to claimants considerable expense and delay.

"In geology, and among miners, veins or lodes imply generally an aggregation of mineral matter found in the fissures of the rocks which inclose it, but are of great variety, veins differing very much in this formation and appearance. 'Lode' is a term in general use among the tin-miners of Cornwall, and was introduced on the Pacific coast by emigrants from the Cornish mines, and signifies a fissure filled either by metallic or earthy matter. In several of the mining districts, the terms 'lead' and 'ledge' are employed in the local regulations concerning mines. 'Lead' is used to convey the same idea as 'lode,' while 'ledge' would seem to indicate a layer or stratum of mineral interposed between a course or ridge of rocks.

"Veins may be either sedimentary, plutonic, or segregated, or of infiltration or attrition, depending upon the peculiar formation, or the mode of occurrence of the mineral deposit There is also another form of deposit different from either of those mentioned above, called 'contact-deposit.'

"European miners mention still others, called in England 'floors,' in Germany '*Stockwerke*,' and a form of deposit known as '*Fahlband*.' These latter are, more properly speaking, ore-bearing belts, irregular in their dimensions, but presenting a certain degree of parallelism with each other. Similar in some respects to the Fahlbands, are the metalliferous zones, or 'amygdaloidal bands,' which are said to exist on Mount Lincoln and Mount Bross, Colorado.

"However, if the question were raised, neither of the forms of deposit known as contact-deposit, Fahlbands, or segregated veins, could be accepted as true metalliferous veins; nor could it frequently be made to appear, without expensive excavation, whether the metal in the mine for which a patent is sought occurs in the form of a true vein or not

"But there is no reason for supposing that the terms were employed in their strict geological signification. The plain object of the law is to dispose of the mineral lands of the United States for money-value; and whatever form of deposit can be embraced in the general phrase, 'vein or lode of quartz or other rock in place,' must be sold at the rate of five dollars per acre.

"It is evidently the policy of the government to include as much land as possible under this designation, for the reason that, as the most valuable metals and minerals occur in the several vein-formations, it is desirable that the lands wherein they are discovered should be sold in limited quantities, thereby preventing the few from monopolizing large tracts, which ought to remain open to all for exploration and development; and for the further reason that the government derives a larger revenue from the sale of lands of this description.

"In fine, I include in the first class all lands wherein the mineral matter is contained in veins or ledges, occupying the original *habitat* or location of the metal or mineral; whether in true or false veins, in zones, in pockets, or in the several other

forms in which minerals are found in the original rock, whether the gangue or matrix is disintegrated at the surface or not. . . . .

"Very respectfully, your obedient servant,

"WILLIS DRUMMOND,

"Commissioner."

The Commissioner's geology is an amusing illustration of the danger of indiscriminate cramming on such a subject. But his common-sense is all the more conspicuous on that account. The courts were not at first equally liberal in fixing the scope of the term "lode," which, since 1866, has assumed a vital importance. They attempted to hold fast to the technical definition of a fissure-vein. Thus, in *Foote* v. *National Mining Company* (2 Montana, 402), it was declared that a quartz lode "is a fissure or seam in the country-rock filled with quartz matter bearing gold or silver." In *North Noonday Mining Company* v. *Orient Mining Company* (1 Federal Reporter, 522), the vein or lode authorized to be located is defined as a seam or fissure in the earth's crust, filled with quartz or some other kind of rock in place, carrying gold, silver, or other valuable mineral deposits named in the statute. "It may be very thin or many feet thick, or irregular in thickness, and it may be rich or poor, provided it contains a trace of any of the metals named in the statute." I quote from the digest in Copp's *U. S. Mineral Lands* (edition of 1881), p. 423. The proviso is scarcely intelligible, considering that the statute comprehensively includes all valuable mineral (not merely metallic) deposits.

The case of *Eureka Consolidated Mining Company* v. *Richmond Mining Company*, already cited, settled the point that a lode under the statute need not be a fissure-lode. "We are of opinion," says the court in that case, "that the term, as used in the acts of Congress, is applicable to any zone or belt of mineralized rock lying between boundaries clearly separating it from the neighboring rock." Great apprehension was expressed by some experts,* at the time of this decision, that the principle laid down in it would prove revolutionary in its application, classing whole geological formations or mountain ranges as lodes. But, as the writer then pointed out, the decision simply emancipated judges and juries from the tyranny of technical definitions. They were more free than before to decide on grounds of equity and common sense whether a given zone of rock claimed as a lode should be practically so considered. It was not long

* See *Transactions*, vi, 560.

before the justice of this reply became manifest. In *Mount Diablo Mining Company* v. *Callison* (5 Sawyer, 439), tried, I believe, in 1878, the year after the Eureka decision, Judge Sawyer, one of the three judges who had rendered that decision, limited its application by declaring that while metalliferous rock in place, not in a fissure, may be found under such conditions within clearly defined boundaries as to require recognition as a vein or lode, a broad metalliferous zone, having within its limits true fissure veins, plainly bounded, cannot be regarded as a single vein or lode, although such zone may itself have boundaries which can be traced. Whether this declaration would have been made in the special case of the Mount Diablo, if the light of subsequent developments had been thrown upon that case, I do not purpose to discuss. The principle declared is clearly equitable. A belt of country-rock, containing independent fissure-veins, is not a lode.

In a more recent case, *Holmes Mining Company* v. *Northern Belle Mining Company*, tried in 1883 before the same judge, the theory of the plaintiff was that a certain belt (apparently the continuation of the Mount Diablo belt) was a "compound fissure-vein," according to the definition of Professor Cotta, given, not in his text-book, *Die Erzlagerstättenlehre*, but in an article contributed to the *Berg-und Hüttenmannische Zeitung* (1864, p. 395), on "The So-called Vein-clay-slate of Clausthal." This proposed distinction between simple and compound fissure-veins is adopted and credited to Cotta by Director Groddeck, in his treatise on Mineral Deposits (*Die Lehre von den Lagerstätten der Erze.* Leipzig, 1879, p. 34). I quote his definition:

> "Compound fissure-veins (*die zusammengesetzten Gänge*) consist predominantly of rock—the so-called vein-rock (*Ganggestein*). This is either unaltered country-rock, or it has been derived therefrom by chemical and mechanical metamorphosis. In the vein-rock occur irregularly distributed veinlets (*Trümmer*), or regularly coursing simple fissure-veins (*einfache Gänge*) filled with minerals."

The above-mentioned case was given by the jury to the plaintiff; but I am unable to say, not having seen the charge of the judge, what view was taken by the court as to the legal location of a "compound lode." From the testimony in the case, however, I am forced to infer that this class of lodes was recognized, and it was left to the jury to decide whether the mine in suit belonged to it.

The principle that a legal lode need not be a fissure-vein having been generally accepted, a new difficulty was raised concerning the

term "in place." This has been chiefly confined to cases arising in the Leadville district, where most of the silver-lead deposits claimed under lode-locations lie at or near the contact between limestone and overlying porphyry, and have a comparatively small dip—say 15 degrees from the horizontal plane. This dip renders it an easy and comparatively inexpensive matter to reach the "contact" with a vertical shaft, at a considerable distance from its outcrop; and the whole region was covered at an early day with claims, in most of which there was no visible outcrop. But the proprietors went vigorously down with exploring shafts, and in many cases reached the contact-zone or vein, the outcrop of which was already located by others. Litigation naturally followed; and a series of interesting and bitterly contested cases, running through the last five years, was the result. In most of these cases the Iron Silver Mining Company has been a party. That company was formed by Mr. William Stevens, a pioneer who, for many years after the decay of the early gold-washing operations in California Gulch, near Leadville, had remained in the locality, maintaining faith in its future, and locating and perfecting numerous claims. With much labor and patience, Mr. Stevens traced the outcrop of the "contact" along the sides of California Gulch, and located lode-claims upon it, until he had in all a mile and a half of continuous claims of this character, which were transferred, together with other property (placer-claims, water-rights, etc.), to the Iron Silver Mining Company. When the rush of prospectors came, they swarmed over the hills, and many of them located "on the back" of the Stevens claims, and, profiting by the explorations which had discovered the position of the ore-bearing zone, proceeded to "go for it" with vertical shafts. Confining our attention for the moment to the Iron hill, we may say that from the Stevens's outcrops for a long distance eastward, there was practically but one legal vein known to exist. This of itself would not constitute a strongly exceptional case. The same is true, for instance, as the courts have decided, at the Comstock and at Eureka. But in those cases, the deposit stands so steeply that, although much litigation has been necessary to establish its unity, the point once established has not again been disputed, because it would be too costly an undertaking to pierce the vein by deep vertical shafts far off in the hanging-wall, merely as a preliminary to a fight. Moreover, the cost in time, perhaps, even more than in money, was prohibitory. The occupant of a steeply-dipping lode, working down upon it by incline, in ore, could reach a given point either before his rival could

arrive at it with a vertical shaft through barren rocks, or else so soon after as to leave no time for that most convenient operation, the extraction of ore from the disputed ground—an operation which is usually relied upon to furnish the sinews of war. At Leadville, on the other hand, the deposit was so nearly horizontal, that shafts through cracked and soft rock might reach points far in advance of the inclines from the outcrop, months before the latter. The thousands of prospectors who had not been pioneers and had not made original discoveries, yet would not submit to an application of the law which would exclude them from a share in the ownership of the good things developed by earlier locators, created an irresistible popular feeling against the right given by the law to lode-claimants, of following the lode beyond their side-lines. Moreover, many, even of the earliest locations, had no visible outcrops; and their owners could not foresee what might be the consequences to them of the general exercise of this right. They might, perhaps, follow their deposit into a neighbor's land, provided it was a lode, and they had the apex; but if somebody else should prove that *he* held the apex, they might lose all. Hence they bowed to the popular feeling, and either tacitly or by formal agreement with adjoining owners, established vertical boundaries, drawn through the side-lines of their locations. But the Iron Silver Mining Company, having for a long distance, at least, a clear outcrop, and a well-defined vein, and laying claim to a magnificent property, decided to fight for its rights—and hence "the Iron Mine cases." Since, under the laws of Colorado, the title to real estate cannot be determined by a single trial, if the beaten party demands another, the trials have been more numerous than the disputes. In the course of them, all possible defences have been set up against the claims of the company. In one case, it would be argued that the deposit was not a lode; in another (or in the second trial of the same), that although a lode where the plaintiff worked it, it was barren for some distance between plaintiff's and defendant's workings, and thus lost its identity; or it was cut off by a dyke, and lost its identity in that way; or being so flat, it was a kind of vein not contemplated by the law—a brand new kind, in fact (not departing from the perpendicular, but departing from the horizontal); or the plaintiff had no apex, and, therefore, no right to follow beyond its side-lines; or the plaintiff's end-lines were not properly drawn; and so on. We are concerned at this time with the first class of

defences only—those which denied the character of the deposit as a lode.

In 1879, one of these cases, the *Iron* v. *Grandview* (*Stevens and Leiter* v. *Williams*), came to trial at Denver before Judge Hallett and a jury. From the charge to the jury (reported in the Denver *Weekly Times*, February 19th, 1879, and in Carpenter's *Mining Code*, third edition, Denver, 1880, p. 67) I make the following extracts:

"The language of the act is, mining claims upon veins or lodes of quartz or other rock *in place*, bearing gold, silver, cinnabar, lead, tin, copper, or other valuable deposits. . . . . And, as to the meaning of these words, in place, they seem to indicate the body of the country which has not been affected by the action of the elements; which may remain in its original state and condition as distinguished from the superficial mass which may lie above it. . . . . And when this act speaks of veins or lodes *in place*, it means such as lie in a fixed position in the general mass of country rock, or in the general mass of the mountain. . . . . Now, whenever we find a vein or lode in this general mass of country rock, we may be permitted to say that it is *in place*, as distinguished from the superficial deposit, and that is true, whatever the character of the deposit may be; that is to say, as to whether it belongs to one class of veins or another; it is *in place* if it is held in the embrace, is inclosed by the general mass of the country. And as to the word vein or lode, it seems to me that these words may embrace any description of deposit which is so situated in the general mass of the country, whether it is described in one way or another; that is to say, whether in the language of the geologist, we say that it is a bed, or a segregated vein, or gash vein, or true fissure vein, or merely a deposit; it matters not what the particular description of it may be, in respect to these distinctions, which are observed by geologists in defining the different classes of deposits that lie in the embrace, or are inclosed by the general mass of the mountain. In all cases I suppose that they are lodes if not veins. It may be true that many of these deposits will not come under the description of veins as known to geologists, but if they are not so described—if they cannot be so correctly described—they are, at least, lodes, and are recognized as such by miners in their search for them. In other words, whenever a miner finds a valuable mineral deposit in the body of the earth, as I have described it, he calls that a lode, whatever its form may be, and however it may be situated, and whatever its extent in the body of the earth. The books make some distinctions between beds and lodes, and they make distinctions in the different classes of veins as you have heard from counsel, but these distinctions are not important in relation to this matter of the discovery and taking of these mineral deposits. It has been decided that Congress, in passing this act, intended by this description to embrace and include all forms of deposit which are located in the general mass of the mountain, by whatever name they may be known, and the distinctions which are adopted by geologists in respect to the different kinds of veins, are not important except for one question and for one purpose, which I may invite your attention to further on. So that we may say, gentlemen, with respect to the case which is now before you, that, whether this may be called a true vein or a contact vein, or a bed; whether it lies with the stratification or transversely to it, the matter is of no importance for the purpose of determining this question; it is in any event a lode if it lies in place within the meaning of this

act. And it is *in place* if it is inclosed and embraced in the general mass of the mountain, and fixed and immovable in that position. Perhaps I ought to say further, in view of some things that were said by counsel in the argument, that it is not material as to the character of the vein matter; whether it is loose and disintegrated, or whether it is solid material. In these lodes the earth that is found in them, the earthy matter which may be washed or treated with water or steam, is often the most valuable part. It was never understood here or elsewhere, so far as I know, that such earthy matter was not embraced in the location because it was of that character. It is the surrounding mass of country rock; it is that which incloses the lode rather than the material of which it is composed, which gives it its character; so that even if it be true, as counsel have stated in the course of their arguments, that this is mere sand, is a loose and friable material which cannot be called rock in the strict definition of that word, if that be true, it does not affect the character of the lode If it were all of that character it would still be a vein or lode *in place*, if the wall on each side, the part which holds the lode, is fixed and immovable. . . . . .

"This brings us to a question, gentlemen, which really is the important question in this case, and that is whether there is any lode in the position which has been mentioned by the witnesses; and in that connection, in the consideration of that question, the character of the deposit, as to whether it is a true fissure vein, or a contact deposit, or a bed, or something of that kind, is of some value; because in respect to fissure veins we accept the cavity or chasm, which is found between walls and filled with what they call vein-matter, as indicating or showing the existence of the lode, even if the matter which is found in it is not very valuable—that is, if there is anything which usually accompanies valuable ores or minerals. But in respect to this kind of deposit, my impression is that it is to be known, called, and regarded as an irregular deposit; one which, if it should be interrupted for any considerable distance—that is, if what they call the contact or junction between the porphyry and lime should become barren for a considerable distance—that it should no longer be called a lode. As I understand it, this line which exists, which always exists when there is a union of rocks of different ages and different formation, may carry ore or it may not; it may be productive or it may be barren; and if this should be found at any point in its course to become barren, and remain so for any considerable distance, I do not see how it could be called a lode in that part of it so that it could be followed with the result to claim what lies beyond. I should say that with reference to such a line of contact between rocks of different formation, that to find that line of contact in one place, unless there were in it valuable minerals which were carried along with something like a continuous course along the line of contact, that no lode would be discovered. It could not be said that any had been found until such minerals were found. I do not mean by this that any slight interruption for a few feet of the valuable part of the ore would have the effect to show that the deposit was broken in its continuousness. I do not mean that, nor do I mean that if any dyke or other extraordinary foreign matter should be interposed in the course of the lode so as to cut it off, and it should follow on immediately after that interruption, that would be regarded as such a displacement in the continuity of the deposit as would deprive it of its regular character. Whenever it may appear that the fissure has existed at one time, or at any time, with a continuous body of ore in it which may have been interrupted by some subsequent convulsion, the character of the deposit would remain the same as if the interruption had never occurred. But if there was such an intervening space in the contact, as these witnesses call it, barren in its continuity, as might show a separate and

distinct body of ore, which had always been such, I should say that it would not pass with the grant of the first. It may help you, gentlemen, for me to express this in other language, and ask you to extend the line which is laid down on that map (showing), for some distance further, and to suppose that in the course of that line, we may say that you find that there is, at the head of the deposit, that nearest the surface, a hundred feet or more of continuous ore lying upon the line between the porphyry and the lime, and then there should be an interruption of a hundred feet or more of this contact which is perfectly barren; the lime and the porphyry coming together carrying nothing whatever; and below that again, another body similar to that which was found at the head, the position which I think might be taken upon this, the position of these ore bodies, would be that there would be two lodes rather than one, the first above, and the second below; but if there is a continuous body of ore, or practically continuous, and there is no such interruption as exhibits other than a casual and fortuitous displacement, then it would be one lode. . . . .

"There may be other deposits in that neighborhood, gentlemen, which show entirely different features, or show the same features, but whether that be true or not, is not a matter for present consideration. We determine these questions only upon what appears in this case, and without reference to any others that may arise in the same locality. Other deposits in this neighborhood may be of an entirely different character; they may be such as cannot in any sense be called lodes at all Whether this is true or not, is not for present consideration. We determine this case, as I said before, upon the evidence given here, leaving other questions which may arise in respect to other locations to the facts as they may be developed in respect to them.

"Some of the witnesses—one in particular—was of the opinion that the ore in this deposit was not found in place until a point had been reached east of the east line in the iron location; others, the witnesses of the plaintiffs, were very confident that it was found as indicated upon the map, at a point where the shaft-house is, there within those lines. That is an important question, gentlemen, because the point where it is found in place determines the ownership of the vein. In other words, if the point at which it is found in place is not within the plaintiff's location, they cannot claim any right to go beyond the limits of their patent and pursue it elsewhere. I think you understand that point pretty well by this time."

The definition here given to the term "in place" is too narrow. Neither the usage of science nor the usage of practice requires that rock in place shall be wholly inclosed in other rock also in place. The term is not without elasticity; but its fundamental meaning is, that the rock occupies with relation to the mass of the adjacent rock the same position as when it assumed its present general character. It is not, in other words, mere boulder or débris, transported from its original position. The possible vagueness of the term arises from two sources: First, All our sedimentary rocks have been deposited by water, either as mechanical or as chemical precipitates. While forming as rocks, therefore, they might not be considered as in place. Practically, the distinction arises with regard to the hard "cements" of the ancient river-beds, which are as really rock in place *now* as any other conglomerates. Yet the General Land Office

(see letter of Commissioner Drummond, February 12th, 1872, Copp's *Mining Decisions*, p. 78) has decided that they do not come under that decision; and they are uniformly patented as placers. Secondly, A mass of rock may not be really in place as a whole, because it has been dislocated and moved from its original position; yet if it is a large mass, this dislocation is in common usage not regarded as preventing the application of the term "in place;" and certainly the subordinate parts of such a mass are considered as in place. But the notion conveyed in the above-quoted charge to the jury, that rock in place must be embraced in the general mass, is untenable. Is not the top of a granite mountain in place? Yet it has no rock in place above it, and it may have débris upon it. Or suppose a quartz-lode, lying wholly within the mass of a slate mountain. It is clearly in place, according to the above definition. Now let the mountain be so affected by frost and rain that the surface is decomposed and removed, until the side of the harder and more resisting quartz-lode is exposed. Then, forsooth, the lode, though it has not budged an inch or yielded an ounce of its mass, is no longer in place. This is not an imaginary instance. I have seen such veins. There is a notable instance on Red Mountain, near Silver Peak, Nevada.

A still more ludicrous application of this definition might be made to a case in which a lode crops out like a wall—a case so frequent as to have given rise to the use of the word "ledge" as a synonym for "lode." Here the lode is actually standing in the midst of the débris produced by the disintegration of the surrounding surface; and it would not be "in place" according to the above definition! It is unnecessary to argue the matter further; yet I cannot forbear to point out that by this definition no part of a mountain, or of the earth's crust can be in place; for if the top layer be not in place because it has no rock in place over it, then the next layer is in the same predicament, and so on.

The worst mischief couched in this definition is indicated by another passage in the charge above quoted, in which the court instructs the jury that the point where the vein is first found in place (proceeding downwards from the outcrop) determines its ownership. Taken together with the strict definition already criticized, this instruction opened a door through which any jury that chose to do so might walk away with the rights of locators under the law. For the majority of lode-outcrops are more or less weathered and disintegrated, and where the lode is harder than the country-rock, one

or both walls are even more affected by decomposition than the lode. Yet miners have no difficulty in determining after a little exploration, that such lodes are in place; and when not only the lode, but one of its walls also, is in place, the miner is satisfied that he has "found the lode," and proceeds to locate his claim upon it. It is unnecessary cruelty to say to such a locator that until the other wall is so solid that a jury cannot be persuaded that it is débris, he has no lode at all; and that the lode begins to exist just beyond his side lines, where his neighbor, who never found it at all, has located a claim on the surface and gone down with a vertical shaft "for luck," or for plunder. I shall recur to this important matter in connection with other decisions.

A further feature of the above-quoted charge requiring comment, is the declaration that the contact zone in this case was not a vein unless it was continuously ore-bearing—or, to take the limit fixed by the court, if a barren interval of a hundred feet on a given line should exist in it. The court here overlooked the overwhelming geological probability that in such a case ore-connections exist on some other line than the one actually exposed in the workings. In the Eureka-Richmond case, the defendants relied largely upon an alleged barren interval of 900 feet, shown by a certain drift between two ore-bodies. But other evidence at hand in that case convinced the court that the zone containing these bodies was one in origin and character; and came under the comprehensive definition announced in these words of the Eureka decision: "It [the term 'lode' as used in the acts of Congress] includes all deposits of mineral matter found through a mineralized zone or belt coming from the same source, impressed with the same forms, and appearing to have been created by the same processes."

The untenable distinction set up by the court in the Grandview case furnishes its own comment in the paragraph quoted above, in which it is declared that other deposits in the neighborhood may or may not show the same features as the one in suit, but that they are not to influence the decision of the present case. There being but one contact-zone known in the neighborhood at the time, the effect of the ruling of the court attaching vital importance to barren intervals in it, was that one locator upon the outcrop, being lucky enough to put down his incline in the axis of an ore body and to avoid the barren spots, would be held to have a lode, while his next neighbor, being less fortunate, would have no lode, or would lose his right to it, though both were located on the same zone, and neither

could have foreseen his fortune. It certainly was not the intent, nor do I think it the necessary construction, of the law, that the acquisition of mining titles should be reduced to such bare gambling as that.

A little later, on motions for preliminary injunctions, in *Leadville Mining Company* v. *Fitzgerald et al.* (Carbonate-Little Giant case) and *Stevens and Leiter* v. *Murphy et al.* (Iron-Luella case), Judge Hallett said (as quoted in Carpenter's *Mining Code*, p. 74, and Copp's *United States Mineral Lands*, p. 356—the two versions differ slightly in unessential particulars, and each contains passages not in the other, but the one I cite is substantially in both, except the first sentence, which is omitted by Carpenter):

"Section 2320 of the Revised Statutes refers to veins and lodes in 'rock in place,' and of course no other can be brought within the terms of the act. After careful consideration, it was thought that a vein or lode could not be in place within the meaning of the act, unless it should be within the general mass of the mountain; it must be inclosed by, or held within the general mass of fixed and immovable rock. It is not enough to find the vein or lode lying on the top of fixed or immovable rock, for that which is on top is not within, and that which is without the rock in place cannot be said to be within it."

Here the court misquotes the statute, which speaks of veins or lodes *of* rock in place, not *in* rock in place. One might suppose this to be a typographical error, but for the argument which seems to be based upon it, and falls to the ground without it. "That which is without the rock in place cannot be said to be within it," says the court. We might irreverently reply, "Well, don't say so, then; nobody asked you to." The question of the law is not whether the lode is within or without rock in place, but whether it *is* rock in place; and the lode itself may be in place, though both walls be débris or air. The condition of the country-rock is collateral, but not controlling, evidence as to the character in this respect of the lode.

It is unfortunate that this point has not yet been settled by the United States Supreme Court. Justice Miller of that court, sitting on the second trial of the Grandview case, in July, 1879, charged the jury at considerable length, but passed over this subject lightly, though it had been made so prominent in the charge on the first trial. The charge of Judge Miller was reported in the Denver papers in July, 1879, and from this report I take the following sentences, which comprise all that concerns the meaning of the term "in place."

"And here I want to say that by rock in place, I do not mean merely hard rock, merely quartz rock; but any combination of rock, broken up, mixed with mineral and other things is rock within the meaning of the statute. . . . .

"I give that instruction [that the mineral must be of quartz or other rock], but with the distinct understanding that all this substance, between the porphyry and limestone, that has been explained to you, which contains mineral—I mean which contains ore—is rock in place."

After quoting and adopting the definitions laid down in the Eureka-Richmond case, Judge Miller added:

"I am aided also by my brother Hallett, whose experience is greater than mine in this matter, and who has also given the definition of the word which I propose to read to you as the law: 'In general, it may be said that a lode or vein is a body of mineral or mineral-bearing body of rock within defined boundaries in the general mass of the mountain.'"

It will be seen that these statements do not clearly meet the question, whether rock may be in place without being embraced wholly by other rock in place. On another point, however, the peculiar nature of the contact-zone in suit, and the effect on the title to it of interruptions in its ore-bearing character, Judge Miller overrules Judge Hallett's previous charge. He says:

"The eighth instruction—'Although the jury believe from the evidence that the plaintiffs are the owners of a vein of quartz rock in place, yet if such vein on its course toward the land in dispute, be interrupted for a considerable distance, then it ceases to be a lode or vein, so as to give the plaintiffs the right to pursue it into the adjoining land, and in such case the plaintiff cannot recover.' I refuse that instruction. In the first place the evidence is uncontradicted—at least so little contradicted I would not dare to put that to the jury—that that main incline has metallic ore in it from beginning to end, as far as it has been carried; and in the second place, the words 'considerable distance,' do not convey any accurate conception. In some cases a mile would be a 'considerable distance,' and in some cases, where a life depended on it, half an inch would be considered a considerable distance. . . . .

" . . . . I say to you further, gentlemen, that the thinness or thickness of the matter in particular places does not affect its being a vein or lode; nor does the fact that it is occasionally found in the general course of this vein or shoot, in pockets deeper down into the earth or higher up, affect its character as a vein, lode or ledge. I say to you, further, that a total interruption of the ore-matter, if the contact remains on each side, the limestone and porphyry are still preserved, and the vein of mineral matter is found within a short distance further on, pursuing that same contact, it is still a part of the same vein. In short, if there is a general and pervading continuance of this mineral matter, with a casual and occasional interruption, but pursuing the same general course, bounded by the same rocky material above and below as far as you can trace that until it breaks off totally and is interrupted for a very large distance, it is a vein of rock or mineral matter. Now I think you

will have no difficulty in applying these definitions, since the evidence here is almost uncontradicted that there is such a sheet of matter as is spoken of. All the witnesses agree that there is a substratum of limestone and a superstratum of porphyry; all agree, even defendant's witnesses, that they come to a point where that contact is so narrow, that only a sheet of paper could be got into it, but still it has the well-preserved distinction—the porphyry above, the lime below, and, although in some instances to the south, some to the north, and some occasional spots in the levels, it is stated by the defendant's witnesses, that no more vein matter has been found; yet you must, I think, come to the conclusion, that on the whole, and taking the course which this matter is in contact from the line of the plaintiff's location to the line of the defendant's location; taking the course of that large incline shaft, driven by the plaintiffs from where they first discovered it to where it meets the defendants—it is for you to say, from the testimony, not for me to find for you—but I can see no reason why you should not say there is a continuous vein of mineral from the opening shaft, the plaintiff's shaft, to the point where it reaches the Williams shaft. If that is true, if you find that to be true, why, notwithstanding these casual interruptions in various directions, notwithstanding the widening, the narrowing, the deepening, and the shallowness of the vein; notwithstanding it has, in some places, acknowledged diversions down into the ground, still, if the miner is able to pursue, and has been able to pursue it in the vein; notwithstanding these interruptions, you are to call it a vein, and treat it as a vein within the meaning of the act of Congress."

It is evident here that the court did not intend to let the jury accept a gap of a hundred feet as enough to separate "two lodes," both in the same contact-plane, and the lower edge of one and the upper edge of the other constituting the boundaries of the gap. On the other hand, Judge Hallett, who did attach that degree of importance to a barren interval, was careful to say, that a mere dyke cutting through the vein would not destroy its legal continuity. But in January, 1884, in the case of *Louisville Mining Company* v. *Iron Silver Mining Company*, Judge Goddard charged as follows (reported in the Leadville *Daily Herald* of January 20th, 1884):

"You are further instructed, at the request of the plaintiffs, that evidence has been introduced by the plaintiffs showing that from near the south end of the McKeon level, upon the Iron claim, a porphyry dyke exists northeasterly across the claims of the defendant company into the Louisville claim, and some twenty feet to the west of the Louisville shaft. That the said dyke cuts upward through the limestone and crosses the plane of contact and into the porphyry hanging wall at the points along its course, and in so doing it cuts through and entirely obliterates the line of contact between the lime and porphyry. The defendant company has, on the other hand, introduced evidence showing that even though there should be an intrusion of gray porphyry through the limestone, at defined points along the line at which the plaintiffs claim the dyke cut its way, yet, nevertheless, it does not cut across the plane of contact, nor does it destroy the continuity of the vein, and that the dyke claimed by the plaintiffs' witnesses does not exist. It is for you to determine from this conflicting testimony what the facts are in relation to the alleged

dyke. You are instructed, that if you believe from the evidence that the dyke exists, as claimed by plaintiffs' witnesses, and that it cuts through and destroys the plane of contact, entirely separating the mineral bodies upon the north and south thereof, so that you cannot reach the one through the other along the plane of contact, or through or along the crevice, then the ore and vein material, with their inclosing walls to the north and to the south of the said dyke, constitute two separate veins or lodes, and the defendant company has no right under the law to go to the south of the said dyke by virtue of the possession of the apex of the vein, if such exists within any of their mining claims."

The lot of a Leadville locator is truly not a happy one. If his outcrop is disintegrated, or one of his walls is loose, or his vein pinches, or a dyke cuts through it, he has few rights which a jury is bound to respect. The long and short of it is, as one of the counsel in the Louisville case was bold enough to say in the court, that the Leadville people are determined to keep locators within their side-lines; and the rulings of the courts have furnished technical pretexts for carrying out the "common law of the district."

The latest ruling of Judge Hallett which I have seen, is contained in his charge to the jury in the case of *Iron Silver Mining Company* v. *W. S. Cheesman et al.* (Iron-Smuggler case). I do not know that it has been printed. I quote from a manuscript copy furnished to me. The charge was delivered at Denver, June 10th, 1882.

"To determine whether a lode or vein exists, it is necessary to define those terms; and as to that, it is enough to say that a lode or vein is a body of mineral or mineral-bearing rock within defined boundaries in the general mass of the mountain. In this definition, the elements are the body of mineral or mineral-bearing rock, and the boundaries. With either of these things well established, very slight evidence may be accepted as to the existence of the other. A body of mineral, or mineral-bearing rock in the general mass of the mountain, so far as it may continue unbroken and without interruption, may be regarded as a lode, whatever the boundaries may be. In the existence of such a body, and to the extent of it, boundaries are implied. On the other hand, with well-defined boundaries, very slight evidence of ore within such boundaries will prove the existence of a lode. Such boundaries constitute a fissure; and if in such a fissure ore is found, although at considerable intervals and in small quantities, it is called a lode or vein."

It is sufficiently evident that under the various definitions and rulings above quoted, the title of the mining locator is not only uncertain at the start, but can never be made certain. It remains always a question for a jury to decide, whether his deposit is a lode or not; and it may be a lode to-day, and cease to be a lode by reason of further developments to-morrow; or one jury may pronounce it a

lode, and another not. The experience of the Iron Silver Mining Company at Leadville is an illustration. Of several suits, all turning upon the same geological and legal state of facts, the company won some and lost others. And in the later trials the company was invariably defeated, because "popular sentiment" was against it. Yet it will be admitted that the use of any law regarding the title to property is, that having complied with the law, an owner cannot afterwards be robbed and denied his remedy simply because he is odious. If the jury verdicts at Leadville had been clearly contrary to law, they could have been set aside. But they were not contrary to law. The law, vague or silent on certain points, was construed by the courts in such a way (whether necessarily or not) as to leave the jury great latitude. They had only to choose which witnesses they would believe as to obscure features of the lode, and on any one of half a dozen points they could, at will, decide it to be a lode or no lode.

Moreover, there is, as I have already indicated, a certain argument of equity, not without force, as to the application of the United States law to veins of not more than 15 degrees dip—called "blanket-lodes" in the West. Congress might have ordained some different rules for these lodes. They did constitute under the old German laws a separate class. I do not see that the operation of the law would have been improved by this distinction. It would simply have introduced a new question of fact for witnesses to quarrel over, and a new peril for mining locators. But however that may be, Congress did not make the distinction; and the attempt to import it into the administration of the statutes as they stand is vain.* The moral of the whole matter is that the law itself is at fault, and often works or permits substantial hardship, or even injustice. But the only way to treat it is to enforce it or change it. Meanwhile, it must be remembered that hardship is not necessarily injustice. The first locator complying with the law should obtain a clear title to something. A later locator or prospector may want part of that something ever so much; he may think he is going to get it, or has got it; yet his disappointment is not unjust to him, however hard it may be. What is unjust is the requirement of

* "It cannot be presumed that Congress intended to prescribe a rule for one class of fissures, leaving others unprovided for. As those acts were apparently intended for all lodes, it is not for the courts to say that they shall be confined to lodes which have a certain position in the earth." Judge Hallett to the Public Lands Commission.—*Report*, p. 270.

conditions which nobody can understand, or be sure he has fulfilled, and the giving of a title in return which nobody can fully trust; and this injustice will, I fear, remain until the attempt to base extra-lateral rights upon undeveloped and uncertain geological conditions shall be abandoned, and the vertical boundary-planes shall become at once the inviolable limits and the impregnable defences of the locator's rights.

In justice to Judge Moses Hallett, whose decisions have been criticized in this paper, it should be added that while he has attempted to construe the law under great difficulties, and in some instances may have given it a construction which it will not bear, he recognizes clearly its imperfection, and favors its radical reform. In a letter to the Public Lands Commission* Judge Hallett says:

> "It is safe to say that the greater part of the legal complications for which mines are notorious over all other property, grows out of the practice of dealing with lodes as distinct and severable from the earth in which they may be found. In condemnation of that policy it is only necessary to say that very many lodes have not that character, and of those that are pretty well defined it is often difficult and sometimes impossible to distinguish one from another. If we can return to the common-law principle which gives to the owner of the surface all that may be found within his lines extended down vertically, we should avoid hereafter fully one-half the controversies that now embarrass the mining industries of this country."

The "common law principle" does not, as Judge Hallett seems to imply, forbid the separation of the mineral right from the surface ownership. This has been shown on a preceding page. But he is perfectly right in his main proposition, and has clearly indicated the heart of the trouble. The government, in exercising its undoubted right to separate the two properties, has violated, not common-law, but common-sense, by conveying a thing which it is difficult to recognize, describe, and bound.

II. The Apex.

As we have seen, the extra-lateral title of a lode-claim is controlled by the possession of the "top or apex." These terms appeared for the first time in the act of 1872. They were not miners' terms. I have reason to believe that they were used instead of the word "outcrop," in order to cover "blind lodes," which do not crop out. The conception of an apex, which is properly a point, was probably taken from the appearance of a blind lode in a cross-section

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* *Report of the Public Lands Commission*, Washington, 1880, pp. xxxvii., 269.

where the walls appear as lines, and the upper edge as a point. The term may also have been intended to cover the imaginary case of an ore-deposit which terminates upwards in a point. We may, however, dismiss from consideration the case of a simple point and safely assume that the apex is the same as the top, and is either a line or a surface.

A few definitions of the apex may be quoted with advantage before further discussion of it. The following are taken from the Report of the Public Lands Commission, transmitted to Congress by President Hayes, February 25th, 1880. This Commission, consisting of Messrs. J. A. Williamson, Commissioner of the General Land Office, Clarence King, Director of the Geological Survey, A. T. Britton, Thomas Donaldson, and J. W. Powell, issued a circular containing a series of questions, to which numerous answers were received. Under the head of "Lode Claims" the fourth question was (in part):

"What do you understand to be the top or apex of a vein or lode?"

Among the answers to this question were the following:

1 "The highest point at which the ore or rock is found 'in place,' or between the walls of the vein, and not a 'blow-out,' or part of the ledge broken down outside the walls." (John Wasson, United States Surveyor-General, Arizona, p. 1.)

2. "The croppings or the exposed surface of the vein or lode." (Thomas Waser, land-attorney, Eldorado County, Cal, p. 229)

3. "The highest point at which it approaches or reaches the natural surface of the ground" (William N, Byers, Denver, Col., p. 259)

4. "The highest point of its outcrop in rock in place." (S. W. Hill, mining engineer, Leadville, Col., p. 279.)

5. "That point at which the vein enters or emerges from rock in place." (Henry Neikirk, miner, Boulder, Col., p. 300.)

6. "The top or apex is generally understood to be that part of the lode that is first discovered. A vertical lode has its apex at the surface." (H. W. Reed, United States Deputy Mineral Surveyor, Ouray, Col, p. 303)

7. "Where the mineral-bearing crevice-matter is first met, either on the surface, or, as in blind lodes, underground; but wherever it is met there begins the apex." (Carl Wulsten, United States Deputy Mineral Surveyor, Rosita, Col., p. 316.)

8. "The croppings or highest point of the ledge appearing above or discovered beneath the surface." (William Hayden, lawyer and mine-owner, Deadwood, Dak., p. 321)

9. "The highest point of the centre of the ledge." (Daniel Bacon, Boise City, Idaho, p. 329.)

10. "The outcrop in the highest geological level, whether this is accidentally higher or lower than some outcrop caused by denudation or slip." (W M. Courtis, M. E., Wyandotte, Mich., p. 339.)

11. "Where it comes through or to the surface of the rock in which it is

incased, though it may be covered, and sometimes is, with twenty or thirty feet of loose earth." (Wesley P. Emery, miner, Butte City, Montana, p. 352.)

12. "That portion of the lode along its course which outcrops to the surface, or, if 'blind,' which comes nearest to the surface." (Walter McDermott, M. E., Lewis and Clark County, Montana, p 372.)

13. "The strike or course of a vein is determined by a horizontal line drawn between its extremities at the depth at which it attains its greatest longitudinal extent. The dip of a vein (its 'course downward,' Rev Stat., § 2322) is at right angles to its strike; or, in other words, if a vein is cut by a vertical plane at right-angles to its course, the line of section will be the line of its dip. The top or apex of any part of a vein is found by following the line of its dip up to the highest point at which vein-matter exists in the fissure. According to this definition the top or apex of a vein is the highest part of the vein along its entire course. If the vein is supposed to be divided into sections by vertical planes at right-angles to its strike, the top or apex of each section is the highest part of the vein between the planes that bound that section; but if the dividing planes are not vertical, or not at right-angles to a vein which departs at all from a perpendicular in its downward course, then the highest part of the vein between such planes will not be the top or apex of the section which they include. The strike or course of a vein can never be exactly determined until it has been explored to its greatest extent; but a comparatively slight development near the surface will generally show its course with sufficient accuracy for the purposes of a location. The dip having an exact mathematical relation to the course of a vein is of course undetermined until the strike is determined; but closely approximated by taking the steepest (the nearest a vertical) line by which practically the line of dip in a vein can be followed downward. The top or apex of a vein is usually the first thing discovered. Sometimes a blind lode, so-called, is encountered in driving a tunnel or sinking a vertical shaft, and then of course the top or apex cannot often be found except by tracing it towards the surface by means of an incline. Of course there are irregular mineral depsoits, departing widely in their characteristics from the typical or ideal vein which seems to have been in the mind of the framer of the act of 1872. To such deposits the foregoing definitions will not apply; and in my opinion great difficulty will be experienced in any attempt to apply the existing law to them. I believe, however, that instances of such formations are comparatively rare, none having fallen under my own observation." (W. H. Beatty, Chief Justice of Nevada, p. 399.)

14. "Croppings." (Edward R. Chase, mining engineer, Wells, Nev, p. 407.)

15. "The line such vein would make in its intersection with the surface, calculated from its true dip at each point." (Robert M. Catlin, mining engineer, Tuscarora, Nev., p. 412)

16. "The uppermost part of the ledge between the two walls, although these may be missing." (D. Van Lennep, surveyor, Winnemucca, Nev., p 418.)

17. "In case the vein outcrops at the surface I would call any portion of such outcrop the top or apex. If the vein does not reach the surface, then the highest point to which the vein or lode can be traced is the apex—not necessarily the nearest point to the surface, but the absolute highest point." (Lawrence F. J. Wrinkle, mining surveyor, Virginia City, Nev, p. 436.)

18. "The summit, comb, crest, or highest point on the ridge of a vein or lode." (William McMullen, civil engineer, New Mexico, p. 451)

19. "The upper edge; that part which is first reached or passed, in developing a mine." (George H. Pradt, United States Deputy Surveyor, Laguna, N. M., p. 456.)

20. "The outcrop, or in case of a blind ledge, that line of the vein or lode which approaches the surface the nearest." (Charles M. Rolker, mining engineer, New York, p. 462)

21. "That portion of the vein that is visible in the country-rock when the loose dirt or earth has been removed. Some veins stand up above the country-rock like a wall. The top of such veins would be the highest part of such wall above the ground or bed-rock." (Charles M. Foster, surveyor, Baker City, Oregon, p. 470.)

22. "Its highest point at any given place." (M. T. Burgess, mineral surveyor, Salt Lake, Utah, p. 487.)

23. "The outcrop." (James H. Martineau, United States Mineral Surveyor, Cacheco, Utah, 505.)

24. "The point at surface where the ore is met with; either superficially seen in the croppings or just beneath the surface." (Edward B. Wilder, United States Deputy Mineral Surveyor, Salt Lake, Utah, p. 521.)

25. "Either the outcrop or crevice between walls at the top of bed-rock." (S. W. Downey, United States Delegate of Wyoming p 552.)

26. "The vein at the surface" (Charles W. Cross, attorney, Nevada City, Cal., p. 571.)

27. "Outcrops generally" (E. D Bright, Trinidad, Col., p. 577.)

28. "The width of the vein or lode on the surface; but the United States mining law means the top or apex to be the width of the claim, 600 by 1500 feet." (J. C. Coony, Fort Bayard, N. M., p. 619)

29. "The outcropping of the vein." (William E. Hall, miner, Big Cottonwood, Utah, p. 632.)

30. "Where it has been projected through the country-rock by an acting subterranean agency or force." (Mason M. Hill, Salt Lake, Utah, p 636.)

The foregoing definitions exhibit all degrees of precision and comprehensiveness. Yet neither of them is sufficiently precise and comprehensive to cover all possible cases. No. 13, that of Chief-justice Beatty, is, as might be expected from his long experience and acknowledged ability, the most carefully guarded; yet it seems to be rather an ideal definition than a construction of the law and the common usage upon which the law was based. Nearly all the definitions above given practically agree in one thing, that while an apex need not be an outcrop, an outcrop must be an apex. In this they are probably right, with the exception of cases in which portions of the side of a vein have been laid bare by the removal of one wall, so as to leave the vein exposed. Such exposures might be outcrops; they could scarcely be termed apexes. The trouble with Judge Beatty's definition is, that it seems to require the deep working of a mine before its strike and dip, and from these the proper position of the apex, can be determined. If he had said "the strike is determined by the general direction of a horizontal line drawn midway between the walls of the vein," he would have avoided this objection. But the strike or course of the vein, which is supposed to be followed by

the location upon it, is not necessarily the true strike. In the Flagstaff case (8 Otto, 463) the U. S. Supreme Court used the following language:

"The principal difficulty in the case arises from the fact that the surface is not level, but rises up a mountain in going from the Titus discovery to the Flagstaff. The dip of the vein being northeasterly, it happens that by following a level beneath the surface, the strike of the vein runs in a northwesterly direction, or about 50° west. In other words, if by a process of abrasion, the mountain could be ground down to a plain, the strike of the vein would be northwest instead of west, as it now is on the surface; or, at least, as the evidence tended to show that it is. In that case the location of the defendant in error would have the vein to its right, and the location of the plaintiffs in error would not reach it until several hundred feet to the north of the Flagstaff discovery.

" . . . . We do not mean to say that a vein must necessarily crop out upon the surface, in order that locations may be properly laid upon it. If it lies entirely beneath the surface, and the course of its apex can be ascertained by sinking shafts at different points, such shafts may be adopted as indicating the position and course of the vein, and locations may be properly made on the surface above it, so as to secure a right to the vein beneath. But where the vein does crop out along the surface, or is so slightly covered by foreign matter that the course of its apex can be ascertained by ordinary surface-explorations, we think that the act of Congress requires that this course shall be substantially followed in laying claims and locations upon it. Perhaps the law is not so perfect in this regard as it might be; perhaps the true course of a vein should correspond with its strike, or the line of a level run through it; but this can rarely be ascertained until considerable work has been done, and after claims and locations have become fixed. The most practical rule is to regard the course of the vein as that which is indicated by surface-outcrop, or surface-explorations and workings. It is on this line that claims will naturally be laid, whatever be the character of the surface, whether level or inclined."

In the Grand View case (July, 1879) already quoted, Judge Miller used the following language:

"The top or apex, within the act of Congress, is the highest end or termination of the vein, and this is so, even though at any intermediate point or points, where the vein is continuous, it rises higher than such highest end, it being essential to such 'top' or 'apex' that there be no vein continuing beyond it. It must be the end of the vein which approaches nearest to the surface. That is the substantial meaning of it. . . . .

"The top of the apex of a vein, within the meaning of the act of Congress, is the highest point of that vein where it approaches nearest to the surface of the earth and where it is broken on its edge so as to appear to be the beginning or end of the vein. The word outcrop has been used in connection with it, and in the true definition of the word, outcrop, as it concerns a vein, it is probably an essential part of the definition of its apex, or top; but that does not mean the strict use of the word outcrop. That would, perhaps, imply the presentation of the mineral to the naked eye, on the surface of the earth, but it means that it comes so near to the surface of the earth that it is found easily by digging for it, or, it is the point at which the vein is

nearest to the surface of the earth; it means the nearest point at which it is found toward the surface of the earth. And where it ceases to continue in the direction of the surface, is the top or apex of that vein. It is said in this case that the point claimed to be the top or apex is not such, because at the points where plaintiffs show or attempt to prove an interruption of that vein, in its ascent towards the surface, and what they call the beginning of it, the defendants say that is only a wave or roll in the general shoot of the metal, and that from that point it turns over and pursues its course downwards as a part of the same vein in a westerly or southwesterly direction. It is proper, I should say to you, if the defendants' hypothesis be true, if that point which the plaintiffs call the highest point, *the apex*, is merely a swell in the mineral matter and that it turns over and goes on down in a declination to the west, that is not the true apex within the statute. It does not mean merely the highest point in a continuous succession of rolls or waves in the elevation and depression of the mineral nearly horizontal."

Upon this ruling was based the definition given to the word *Apex* in the writer's *Glossary of Mining and Metallurgical Terms* (1881) viz.: "In the U. S. Rev.* Statutes, the end or edge of a vein nearest the surface."

Coupled with other rulings in the Colorado courts, this definition locates the apex where the vein is found nearest the surface with both walls in place; and hence in many cases the apex, as thus defined, might be so far from the outcrop, or from the highest exposure of the vein with one wall in place, as not to be within the same location.

But another and most troublesome point has been raised concerning the apex. It will be noticed that all the definitions are somewhat vague as to whether it is a point, line or surface. But this is an important question, because the condition of extra-lateral title under the law is that the apex shall be within the claim. Now it often happens that the location does not cover the entire width of the lode. This may happen through ignorance on the part of the locator, or an erroneous determination of the centre-line of the lode. Or it may be that the lode is wider than the local regulations permit the location to be. According to the statement of Mr. Burgess to the Public Lands Commission (*Report*, p. 487) this is the case with the Flagstaff, South Star and Little Cottonwood mines in Utah. It is also the case with the Richmond and Eureka mines on Ruby Hill, Nevada. Yet in the Flagstaff and the Eureka decisions (both leading cases, one of them in the U. S. Supreme Court, and the other tried before three eminent judges, one of whom was Justice Field of the U. S. Supreme Court) this feature was not considered by the

* Expanded by an ambitious compositor into "Revenue" Statutes, and thus finally published (*Transactions*, ix., 102), to the mortification of the author.

Court as affecting the extra-lateral rights of locators. So far as I know, it was not raised by either side. But in the case of *G. W. Hall et al.* v. *Equator Mining and Smelting Company et al.* (*Colorado Central* v. *Equator*), Judge Hallett pronounced in the U. S. Circuit Court of Colorado, February 3d, 1879, an opinion from which the following extracts are taken.*

". . . . As to all of the disputed ground, the principal question affecting the whole lode is whether by locating a part of the width of outcrop the whole may be taken—of several collateral locations on the course of a lode where the top or outcrop is of sufficient breadth to admit of more than one, are not all of equal dignity and force within their own lines? This question will admit but one answer, with such modification as may be hereafter suggested. The act of 1872 certainly requires a location to be along the course of the lode and to include the top of it, and it is believed that the act of 1866 is of the same effect. Defendants' location was made under the act of 1866, and probably some discussion of that view of the act would be appropriate in this connection. But it may be enough to say that defendants assumed to take the whole lode into their location; and if they failed to get the whole, either by their own omission or because of some restrictive provision of the local law, the result is the same. In either case, they can not now claim more than was taken by the location. The same rule is applicable to plaintiffs' location, and as to both of them it is no answer to say that the law would not admit a location of sufficient width to take the whole lode. If the law is illiberal, it is not for that reason the less controlling. If, however, a right to the entire lode can not be asserted under a location covering a part only of its width, as seems to be obvious, the location may be valid for the part described in it. If it is on the top of the lode, it is within the act, and so it ought to be good for the part within the lines extended downward, vertically, if for no more. Generally it may be said that a patent for a lode, issued under one of these acts, will convey all valuable deposits within the tract described, except such as may belong to lodes and veins which outcrop elsewhere and come into the tract in their downward course. *Prima facie*, the patentee must be the owner of all that lies within his lines. He has also the right to pursue veins and lodes which he holds by their outcrop into other territory, but in that the burden of proof is cast upon him to show the origin and continuous course of the vein out of his own land. Adjacent owners may equally invoke the rule which protects their possession, and demand full proof of the right to enter their territory. That is to say, every owner by patent shall be sovereign in his own domain; and whenever he goes beyond it, he shall recognize the equal right of others to the same protection. And thus it may be true that each of several locators on the same vein or lode will own all within his lines without being able to go beyond them. For as to his right to go into other territory, he can only do so in pursuit of a lode or vein that has its top and apex wholly on his own ground, and, having but a part of the lode in his territory, he can not comply with that condition. This appears to be a clear inference from the language of the act. The right given relates to veins, lodes, and ledges, the tops of which are inside the surface lines, which obviously means the whole and not a part. If, then, two or more collateral locations be made on one and

* See *Engineering and Mining Journal*, March 22d, 1879. The abstract reported in Carpenter's *Mining Code*, 3d ed., p. 65, is much condensed.

the same vein, and the vein appear to be homogeneous throughout its width, we are authorized to say that each shall be confined within his own lines drawn down vertically. But what shall we say when there are veins within a vein or lodes within a lode, or when, as in the great Comstock, the vein is on one side of the lode, and a considerable body of crevice matter on the other side?

"The occurrence of veins in other veins, applying the word first to the sheet of ore which is often called the pay-streak, and again to the general mass of the crevice embracing the ore and gangue, will not be controverted. In this case, the witnesses have spoken of several veins in the crevice matter, using the word in its restricted sense to describe the ore as distinguished from the great body of the lode, and this is a matter of ordinary experience in the courts of the State, as we all know. This corresponds with a definition found in Webster's Dictionary, where it is said that the word is often limited in the language of miners to a layer or course of metal or ore. So, in works on topography, fissures are mentioned as occurring within other and probably older fissures, which if filled may furnish the conditions of a vein within another and larger vein. It may be that the word is generally applied to the whole body of the crevice; but if it is also used in a restricted sense to designate the sheet or mass of ore in which the pay is found, it may be taken to mean the last as well as the first. I have not heard the word lode used in the same sense; but as it means only a vein carrying ore, it would be even more significant than the latter. The word ledge is not in use with us, and, therefore, it affords no light as to the proper construction of the words with which it is associated in the act. As found in the acts of Congress, I think that the word vein may be taken in the limited sense to which reference has been made, as well as in the larger, and perhaps more usual meaning of a crevice, belt, or zone of auriferous or argentiferous rock. To give effect to it in that way, we need not resort to the nice definitions and subtle distinctions of geological science. It is enough that such is an accepted use of the word among miners, and that it appears to coincide with the intention of Congress. So understood, the word vein, in the Equator patent, may refer to the sheet of crevice of ore that was found on the south wall of the lode; although, by reason of the narrowness of the location, it cannot be said to refer to the entire lode. So also the word vein in the Central patent may be regarded as referring to the sheets and bodies of ore found in plaintiffs' openings, although for the same reason it cannot apply to the whole lode. If all the ore in the lode had been found on the foot-wall, a location at the top would certainly be sufficient to carry the vein, although it might depart on its dip from the lines of survey. No one would then contend that a location to the northward, although on crevice matter, and although the locator should come on the vein in its dip, would thus acquire a right to it. The circumstance that bodies or sheets of ore have been found in the No. 5 and Central ground to the north, so long as there is no union of such bodies with that on the south wall, in no way affects the ownership of the latter. It stands as if no other vein had been discovered in all the lode; and the question is whether, after discovering and locating that vein, the defendants may follow it in its downward course, as distinguished from the lode, or the greater vein, if that word is preferred, of which it is unquestionably a part. If the ore had been distributed throughout the lode (using that word to describe the belt or zone of crevice matter) with anything like uniformity, we should be unable to distinguish between the several parts, and, as we have already said, each party would then be confined to their own lines. But the vein on the south wall is, according to the evidence, quite distinct from the general mass of the crevice and of such strength and continuity as may give it unity and individuality in law and in fact. There are several spurs or off-shoots coming in from the north which

do not appear to affect the character of the vein. And there are some indications of a probable union and consolidation of all the ore-bodies west of the present development; but of these things we need not speak. In deciding this cause, it is enough to say that the vein on the south wall may be held as a separate and distinct location, with the right to follow it in its downward course so long as it retains its individual character. If it shall be found to unite with another vein in the same lode, the rights of the parties will be governed by those principles which are applicable to the union and intersection of distinct and separate lodes. All that has been said respecting this vein is based on the fact, as shown by the evidence, that its top and outcrop are wholly within the Equator ground. . . . .

"If the top and apex of the vein had been found within the Central lines, some questions would arise which were submitted by counsel concerning the force and effect of the patents within the space covered by both locations. In the view which has been taken of the case, however, it has not been found necessary to discuss those questions.

"Briefly to recapitulate all that has been stated at length, we may say:

"First. That the vein on the foot-wall is so far distant and separate from the general mass of the lode that it could be taken and located without including the entire lode in such location.

"Second. That the top and outcrop of that vein from the engine shaft west as far as the development extends, is within the Equator grounds.

"Third. That defendants, having the top and outcrop of the vein in their territory, may follow it in its downward course into other territory, so long as it retains its individual character.

"Fourth. There is no union or junction of veins within the Central ground as claimed by plaintiffs.

"The judgment will be for defendants."

Upon this decision, the writer made the following comments* (here quoted with slight verbal alterations):

"Assuming the facts as the court states them, and accepting particularly its positive declaration that the material between the two 'veins' of ore which it describes as included in one lode, is vein-matter or gangue, and not country-rock, we have to make the following criticisms upon this view of the law:

"1. The subject of the grant contained in a United States mining patent is not a vein of ore, but a vein of quartz or other rock in place carrying ore. Hence, if the court is satisfied that a mass of rock intervening between two seams of ore is vein-matter, the two seams must be held to be parts of the same vein or lode. It is quite true that small veins of ore occur within lodes; but it is not true that the terms vein and lode in the statute have reference to such a distinction. On the contrary, as has been repeatedly held, the words are used in the acts of Congress as interchangeable and synonymous. The phrase is 'a vein or lode,' not 'a vein or a lode.'

"2. The width of the surface location is left to local laws, 'so far as the same are applicable and not inconsistent with" the United States law. This provides that the surface location shall not exceed 1500 feet in length, or extend more than 300 feet or less (except in certain cases) than 25 feet on each side of the middle of the vein at the surface. But the law contemplates also that the locator shall have full

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* *Engineering and Mining Journal,* March 22d, 1879.

right between the end-planes of his location, to the vein on which it is based. If the local law operates to limit that right, it is in so far void, both for 'inapplicability' and for 'inconsistency.'

"3. The surface was, by the law of 1866, not actually granted in full ownership. The Revised Statutes now give to the locator the exclusive title to his surface. The boundaries of that surface claim are all-important to determine several things, to wit: Vertical planes drawn through the end-lines, absolutely bound the locator's rights on the course of all veins; while similar planes, drawn through all the boundary-lines, inclose a space within which, if he finds the tops or outcrops of other veins than the one specified in his patent, he may follow such veins on the dip into the land adjoining.

"4. Do the side-lines of the survey affect the right of the locator to follow and work a vein, outcropping within those lines to the extent of a part, but not the whole, of its width? Such vein may be either the vein specified in the patent, or one subsequently discovered. In the former case, it is presumed by the Land Office, in issuing the patent, that it covers the outcrop of the lode; and the patent consequently gives the right to that lode, and all others cropping or topping within the surveyed and granted ground. But the top or apex of a vein need not be the whole of the vein, from wall to wall; and the demand that both walls of a vein shall be discovered, before it can be claimed and followed, is a very exacting one. In many instances, it could not be complied with at all. The simple rule should be to construe a partial outcrop within the lines as satisfying the law. If an adjoining parallel location contains the rest of the outcrop, the question is simply one of priority of title. The elder location, or, if there be a patent, the elder patent, takes the vein which crops out *within two locations.*

"5. Let us see how Judge Hallett's views would operate. A locates 25 feet in width on each side of the middle line of an outcrop discovered by him, only 50 feet wide; but this 50 feet is the upper edge of a vein which, immediately below, becomes 100 feet wide, so that 25 feet of its thickness extends into the parallel later location of B on one side, and 25 feet into the similar location of C on the other. A can, in this case, claim and work the full width of the vein which he has discovered, and follow it to any depth. But if he had discovered the same vein, at a point where it was 60 feet wide on the surface, he could not have got any right to follow it in depth at all. For the local law would confine him to a surface claim extending only 25 feet each way from the middle line; and hence, 5 feet along each wall of the vein would be left to adjoining claims. The law would not permit him to locate those adjoining claims for himself: and if he could do so, it would help him little; for, as the vein discovered does not crop out *wholly* within any one of the claims, each locator, according to Judge Hallett, 'will own all within his lines, without being able to go beyond them.' The union of the three claims under one ownership could not confer rights which neither of them possessed. Hence, if A, B, and C should sell out to D, D would own the whole outcrop of the lode, and yet have no right to follow it in depth! In short, under this decision, there would be no possible way, under a local law prescribing the width of location above supposed, of obtaining from the United States the mining rights which are contemplated by the Federal laws.

"Or, again, A discovers the foot-wall of a lode, with a seam of ore lying upon it. Very likely there is a similar seam along the hanging-wall, that being a common exhibition of symmetry in the structure of true fissure-veins. He does not know where the middle of the vein is; and he is forced to record his location within a brief period, on pain of losing his title altogether. Necessarily, he locates his claim

to include the foot-wall; and, supposing that his fifty feet in width only limit him as to surface-ownership, and as to claims on possible veins yet undiscovered, he rests in the belief that he has secured a certain length on the principal vein. But on cross-cutting and developing, he finds the hanging-wall to be outside of his surface lines, and is told by Judge Hallett that until the hanging-wall seam of ore comes into the foot-wall seam (which it will not do, as a general rule, unless the lode pinches), he cannot lay claim to it! We might multiply instances to show that this application of local laws regarding the surface-lines, or any application of the surface-lines which permits parallel conflicting ownerships on one vein or lode, and at the same time deprives them, one and all, of the right to follow the lode in depth, unless they can maintain the independence of some particular seam within it, is fatal to security of title.

"6. The case of the Comstock lode, cited in passing by Judge Hallett, proves just the opposite of what he intends. For it is not true, as he supposes, that, in the Comstock, the 'vein' is on one side of the 'lode.' On the contrary, the history of mining on that lode has repeatedly involved the discovery of new ore-bodies to the east or hanging-wall side, and beyond what had been supposed to be the true hanging-wall. If his doctrine were accepted, almost every mining company on the Comstock would have been deprived, at one time or another, of its valuable bodies of ore; and the era of chaos and conflict, arising out of innumerable surface-locations upon seams, strings, leaders, and what not, would have been perpetuated until now.

"7. The two fundamental mistakes which have led to this decision appear to us to be the mistake of supposing that a narrow surface-location can defeat the purpose of the Federal law as to the full mining-right on a discovered lode; and the mistake of saying that, in such a case, though the whole lode may not be held, yet a subordinate seam of mineral in it may be held. Thus, the discoverer of a very wide and valuable lode, impregnated throughout with precious metal, could get no right to follow it in depth; if he could find a thread of ore different from the rest, he might call that a vein, and follow that; but if that should give out, and he should have, say at 50 feet depth, only his homogeneous, impregnated vein, which was too big for his surface-lines, he could not follow that into adjoining ground, and would lose his mine. In other words, the larger and more uniformly valuable is the vein he has discovered, the smaller and more precarious is his title to it."

These comments require some modification. It is not certain that there is, between the specified lode and all other lodes, such a distinction as is implied in Nos. 3 and 4. The language of the Revised Statutes does not make it; and, that being the case, it is questionable whether the language of the patent* as issued by the General

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* The following is the form of a United States Mining Patent, copied from a patent issued in January, 1884.

UNITED STATES OF AMERICA.

GENERAL LAND OFFICE.	MINERAL CERTIFICATE.
No. ——.	No. ——.

To all to whom these Presents shall come, Greeting:

WHEREAS, In pursuance of the provisions of the Revised Statutes of the United States, Chapter six, Title thirty-two, there have been deposited in the General Land

Land Office (which *does* make this distinction) has any legal force. This consideration weakens also the argument of No. 2.

Office of the United States, the Plat and Field-notes of Survey of the claim of on the Lode, accompanied by the Certificate of the Register of the Land Office at in the of whereby it appears that, in pursuance of the said Revised Statutes of the United States, the said did on the day of A.D., enter and pay for said mining claim or premises, being Mineral Entry No. in the series of said office, designated by the Surveyor-General as Lot No. , embracing a portion of Section in Township of Range of the Principal Meridian, in the Mining District in the County of and of , in the District of Lands subject to sale at , containing acres, more or less, and, according to the returns on file in the General Land Office, bounded, described, and platted as follows, with magnectic variation East, to wit:

[Here follows the description of the survey by courses and distances.]

Now Know Ye, That the United States of America, in consideration of the premises, and in conformity with the said Revised Statutes of the United States, HAVE GIVEN AND GRANTED, and by these presents DO GIVE AND GRANT, unto the said and to and assigns, the said mining premises hereinbefore described as Lot No. [etc.],

with the exclusive right of possession and enjoyment of all the land included within the exterior lines of said survey not herein expressly excepted from these presents, and of linear feet of the said vein, lode, ledge, or deposit for the length hereinbefore described, throughout its entire depth, although it may enter the land adjoining, and also of all other veins, lodes, ledges, or deposits throughout their entire depth, the tops or apexes of which lie inside the exterior lines of said survey at the surface extended downward vertically, although such veins, lodes, ledges, or deposits in their downward course may so far depart from a perpendicular as to extend outside the vertical side lines of said survey: *Provided*, That the right of possession hereby granted to such outside parts of said veins, lodes, ledges, or deposits shall be confined to such portions thereof as lie between vertical planes drawn downward through the end-lines of said survey at the surface, so continued in their own direction that such vertical planes will intersect such exterior parts of said veins, lodes, ledges, or deposits: Excepting and excluding [here follow the reservations, if any there be, of town-lots, portions of ground previously patented, etc.].

And provided further, That nothing in this conveyance shall authorize the grantee herein, or assigns, to enter upon the surface of a mining claim owned or possessed by another: TO HAVE AND TO HOLD, said mining premises, together with all the rights, privileges, immunities, and appurtenances of whatsoever nature thereunto belonging unto the said and to and assigns forever, subject, nevertheless, to the following conditions and stipulations:

First. That the grant hereby made is restricted to the land hereinbefore described as Lot No. , with linear feet of the vein, lode, ledge, or deposit for the length aforesaid throughout its entire depth as aforesaid, together with all other veins, lodes, ledges, or deposits throughout their entire

The Equator case was tried again in July, 1879, before Judge Miller and Judge Hallett; and the former instructed the jury that as neither patent covered the apex of the lode, each including only portions of it, neither patentee had the right to follow the lode on its dip; but each would be confined to the portion of the vein included between vertical planes drawn through his boundary-lines. I do not know whether this decision was published, and I am indebted for this brief summary of it, to a distinguished member of the Colorado bar. Its practical effect would be peculiar. The accompanying diagram, Fig. 1, shows a general case, in which the outcrop of a vein appears in two parallel adjacent locations. According to this decision, the locator, B, who has the hanging-wall, will obtain by far the larger part of the vein. Moreover, he can cross the line *bc* and work unmolested, in the ground C, unless some other locator has preoccupied it, which can only be done by the actual discovery of ore within it. Now, unless there be another deposit overlying the vein here shown, such a discovery can only be made by the sinking of a deep shaft in C, to strike this vein; and if B crosses the line before such a shaft has reached the vein, then B makes the

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depths as aforesaid, the tops or apexes of which lie inside the exterior lines of said survey.

Second. That the premises hereby conveyed, with the exception of the surface, may be entered by the proprietor of any other vein, lode, ledge, or deposit, the top or apex of which lies outside the exterior limits of said survey, should the same in its downward course be found to penetrate, intersect, extend into, or underlie the premises hereby granted, for the purpose of extracting or removing the ore from such other vein, lode, ledge, or deposit.

Third. That the premises hereby conveyed shall be held subject to any vested and accrued water rights for mining, agricultural, manufacturing, or other purposes and rights to ditches, and reservoirs used in connection with such water rights as may be recognized and acknowleded by the local laws, customs, and decisions of courts.

Fourth. That in the absence of necessary legislation by Congress, the Legislature of may provide rules for working the mining claim or premises hereby granted, involving easements, drainage, and other necessary means to its complete development.

In testimony whereof, I, , President of the United States of America, have caused these letters to be made, Patented, and the Seal of the General Land Office to be hereunto affixed.

Given under my hand, at the City of Washington, the day of in the year of our Lord one thousand eight hundred and eighty , and of the Independence of the United States the one hundred and .

By the President,
By ——— ———,
Secretary.

discovery of ore in C, and can for himself locate the ground. Judge Miller's ruling, therefore, it will be seen, strongly favors the hanging-wall claimant, and may, under certain circumstances, give him practically the whole of the vein. Judge Hallett's previous ruling,

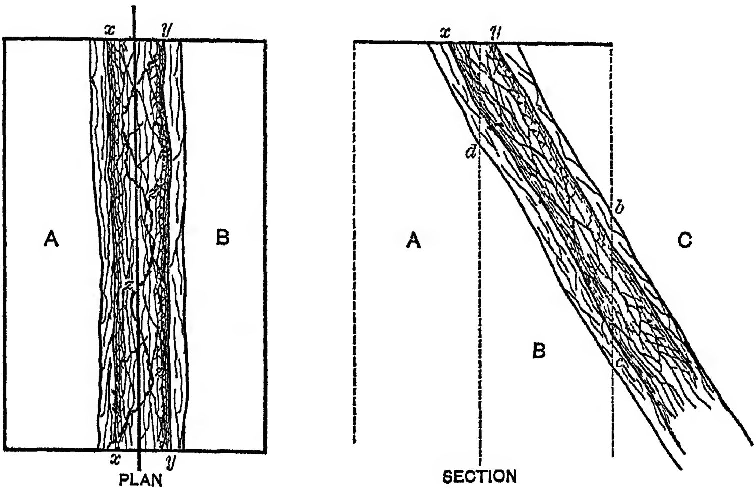

FIG. 1.

on the other hand, would, as one of the counsel engaged in the case expressed it, "saw the lode into slabs," if there were parallel seams of ore in it which would permit such a division, such as x, y, Fig. 1.

According to my recollection—I have no report of the cases before me—rulings were made in Nevada by Judge Rising (May, 1881) and Judge Rives (August, 1881) in controversies between the Richmond and Albion mining companies, declaring in effect that the prior location, though it covered but a part of the width of the apex, would hold the whole vein on its dip. I think the tenor of the decisions of the State courts on the Pacific coast has been in the same direction. But perhaps it would be more correct to say that the point has scarcely been contested outside of Colorado. The prior location has taken the vein as a matter of course. Under the law of 1866, or the miners' customs generally, the question could not arise. The right of discovery and prior location was too potent to permit such interference; and the lines of the surface-location were relatively of much less importance. I cannot help feeling that this fact would considerably influence the Supreme Court in deciding this point—which will reach that tribunal sooner or later, and the sooner, the better. The language of the statute, however, is pretty

positive; and since the grant of the extra-lateral right is an extraordinary one, it is fair to construe its conditions strictly. Until the Supreme Court shall have settled it once for all, we may expect contradictory decisions in the courts below.

A way out of the difficulty suggests itself in the question whether the apex need include the whole vein from wall to wall. May it not be a line? Must it necessarily be a surface? In No. 4 of the comments quoted above from the *Engineering and Mining Journal*, this question is answered in the negative. But the subject is not without great doubt. If the highest *line* along the vein be called the apex, then the mere projections of the outcrop—the last accidents of surface-configuration—would determine its legal course, which might be as crooked as the line *z z*, Fig. 1.* This solution of the problem, therefore, though it would keep within the letter of the law and avoid the absurdity of a lode in which nobody has or could acquire the extra-lateral right, would be extremely difficult of application.

We have thus discussed four different solutions of the problem presented by two parallel, adjoining locations, each containing part of the lode at the surface or apex. Either:

1. Each locator has the extra-lateral right upon his own seam within the lode; or,
2. Neither locator has any extra-lateral rights whatever; or,
3. The prior locator has the extra-lateral right; or,
4. The locator having the highest line along the vein has the apex, and hence the extra-lateral right.

There are two other possible solutions. Either:

5. The footwall location, or,
6. The hanging-wall location, takes the extra-lateral right.

In behalf of the fifth alternative, it might be urged, that the discovery of one wall in place is certainly enough to prove the lode in place, and that the footwall is the more likely to be in that condition near the surface, and to constitute, therefore, the clearer landmark for the true position, dip, etc., of the lode. Under a special statute in Montana (before the U. S. statute was passed), one wall

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* This objection was clearly pointed out by Dr. Persifor Frazer, in a brief discussion of this paper at the Troy meeting. The paper was not read at that meeting in full—a comparatively brief oral statement of a portion of it only being presented; and the discussion is not reproduced here, because the written paper has been so far modified as to supersede it. I believe that the point here named is the only important one for which credit should be given in this connection.

determined the existence of a lode; and since the hanging-wall is more frequently indistinct or disintegrated than the footwall, it was the footwall which the miner most assiduously sought, and upon which he based his claim. Yet, no doubt, a prior discovery of the hanging-wall would defeat it.

Concerning the sixth alternative, I will merely remark that I have heard of one decision which adopted it; but I have been unable to get a report, or even a trustworthy account of it. According to the hearsay which constitutes, in this case, my only authority, a certain judge decided that in a case such as is shown in Fig. 1, the hanging-wall claimant would have the extra-lateral right on the lode, because his claim would at some depth or other (in Fig. 1, at *d* and below) contain both walls; whereas the foot-wall claim would never include the hanging-wall.

Of all these alternatives, No. 3 is undoubtedly the most desirable for the mining industry; and it is to be hoped that the Supreme Court will see its way to adopt it. This could perhaps most easily be done by a liberal construction of the word "within," as simply *not* "without," and by excluding the notion of a third position, neither within nor without the location, as defeating the manifest purpose of the law, and therefore absurd legally, however sound it might be logically.

Still another question may arise concerning the apex. Where a lode, in approaching the surface, branches, and the branches have their outcrops or apexes within different locations, the prior locator is probably, under the Act of 1872, entitled to the lode below the junction. (See section 14 of the Act, or section 2336 of the Rev. Statutes.) For this statute has nothing to say about "dips, variations, or angles;" and, under it, the case described would probably be held to be the union of two veins. But the Act of 1866 contains the phrase just quoted, and moreover clearly recognizes the existing customs of miners, by which "spurs" as well as "dips, variations, and angles" were generally included in the possessory title of the locator upon the main lode. In the case of mines located before May 10th, 1872, it might be a matter for legal decision, which apex was that of the main lode, and which of the spur or feeder. Eminent counsel to whom I have submitted this point, reply:

"It would be a question of fact to be determined by developments and expert testimony as to which claim was located upon the lode, and which on a spur or feeder. That being determined, of course title to the lode carried the lode. The question would have to be decided by the jury, under the instructions of the court.

The court would, of course, instruct the jury in effect, that whichever location they believed covered the principal lode would be entitled to hold it on its dip."

Even under the present statute, it is held by some that this question might arise, and that the relation of the two apexes, as main and subsidiary, might overrule the relation of the two locations in point of age.

Without attempting to discuss the point fully, I will show by one or two instances how it might affect locators.

1. A finds a small vein, locates a claim upon it, and begins to work it. B, attracted by A's success, starts a shaft just beyond A's side-line, over the dip of this vein, and discovers the apex of another vein, on which he makes a later location. At the depth of a hundred feet, the two come together, and a jury decides that B's lode, having been the larger and more profitable of the two, is the main lode, and that poor A, who has pluckily followed his less remunerative vein from the surface, in the hope that it might improve in depth, must now lose it altogether, because it has improved so much! This is a hardship to A, who was the real discoverer, and would have developed the whole mine if allowed to go on.

2. A's vein in the case just described, is the larger of the two, but much less rich. Geologically it was the main fissure; but the vein of B is commercially the main or only valuable lode. How shall the jury decide this?

3. A locates as before, but upon a defined lode, concerning his title to which no doubt ever arises. B makes a later location in the neighborhood, upon another lode altogether. In the course of working, it is found that B's lode receives at the depth of 100 feet, a branch coming from, and having its apex in A's ground. But this branch has never been discovered or worked by A. It is simply one of the "all veins, lodes or ledges, the top or apex of which lies inside" his location. Here the giving of the lode below the junction to A on the ground of priority, would be a hardship to B; and if the jury should pronounce the A branch a mere feeder, and the B branch the main lode, they would do substantial justice.

These illustrations might be multiplied; and the result would be to show that the hardship would be sometimes on one side, sometimes on the other. We may say, however, that there is less real ground of complaint when the principle of priority is made the basis of title than under any other theory of the mining law. The golden rule for courts and juries might well be, "When in doubt, give the

disputed ground to the prior locator." For this rule there are two general reasons:

1. It recognizes the merits and claims of discovery and pioneer exploration, which are essentially among the oldest and deepest foundations of property-rights.

2. It involves the minimum of uncertainty and injustice, because the subsequent locator is warned beforehand, and makes his claim, conscious that it is subject to the prior rights. Hence he cannot claim that he has been surprised or wronged.

III. The Course Downward.

A very important question may arise, as to whether the "course downward" of the law must be the true dip, which, as mining engineers are aware, is the inclination in degrees below the horizontal of the steepest line drawn in the plane of the lode, or the intersection of the plane of the lode with a vertical plane at right angles to the strike.

The act of 1872, by the peculiar form of its extra-lateral grant, already discussed, has laid the main emphasis upon the end-lines; and the dip has become relatively unimportant. But the end-line problems are yet far from settled. Many of them have scarcely been attacked; and in some of them it may be that the proper meaning of the "course downward" may reflect light upon the proper position of the end-lines.

Up to the present time, however, there has been but one point decided with regard to the course downward, namely, that it is the general inclination of the lode entering the mass of the earth; that it includes local rolls and variations even when they are so extreme as to give the lode temporarily an actual upward course; and that it may be said to "depart from the perpendicular" when it approaches without completely reaching, a horizontal position. I will not stop to quote authorities; these decisions are obviously just. But they do not settle the question whether (even if the true dip must be followed) the local dip at the point of discovery, or the local dip at the end-line, or the average of the two dips at the two end-lines, or the average dip throughout the claim, or the average dip of the whole lode so far as it can be traced, must be followed.

IV. The End-Lines.

The statute, while giving to the end-lines of the location absolute controlling importance, does not prescribe their direction. It barely

directs that they shall be parallel, without fixing any penalty. The requirement of parallelism has usually been enforced by the Land Office, but patents have been granted (see the Eureka case, already quoted) in which this was not the case—presumably on locations older than 1872; and the shape has been held not to void the patent.

Mr. Wrinkle, mining surveyor of Virginia City, Nevada, submitted to the Public Lands Commission (*Report*, p. 432) the case illustrated herewith in Fig. 2.

The diagram represents the outcrop of a lode LL, dipping as shown by the arrows. On this lode, A makes the first location *aaaa*, and obtains the extra-lateral right between vertical planes drawn through *aa'*, *aa'*. The next location is made by B, who, however, prefers to draw his end-lines *bb*, inclined to the course of the lode, so that his boundaries *bb'* on the dip continually depart

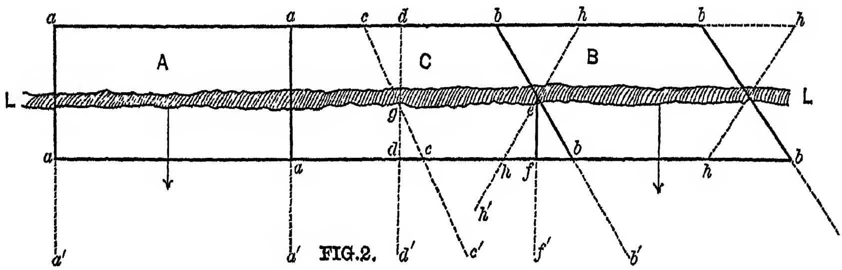

FIG. 2.

from those of A. Each of them has complied with the law; but when C undertakes to lay a third location between them, if he makes one of his end-lines coincide with the end line *a a* of A, he cannot, under the rulings of the General Land Office, make the other end-line coincide with *bb*, the end-line of B, but must run it from the point *e* (the crossing of the lode with *bb*) in the direction *ef*, parallel with *aa*, leaving the triangle *f' e b'*, which nobody can locate, although the claim of C may be much less than 1500 feet long. On this case, the following observations may be made.

1. It is not quite true that nobody can locate the triangle referred to. Whoever—B, C, or another, first finds ore, in the lode LL or any other lode, within the vertical planes *ef'*, *eb'*, can cover it with a surface-location, which will simply lack the extra-lateral rights. This location may have a maximum size of 600 by 1500 feet.

2. If C's only recourse were to take the end-lines *aa*, *ef*, he would not be wronged; for his claim, at any level beneath the surface,

would be just as long as it is at the surface. He would have everywhere the same number of feet on the lode.

3. But in fact C has here the opportunity of doing better than this. He can draw an end-line *cc*, parallel to *bb*, and locate the claim *bbcc*. Then drawing through *g* (at the crossing of the lode) an end-line *dd*, parallel to *aa*, he can locate or cause to be located, the claim *aa dd*.* Then he will be entitled, under the first location to the extra-lateral ground *bcc′ b′*, and under the second, to *add′a′*; and the triangle *d′g c′* will be in the heart of his ground, where nobody can get access to it—provided the vein dips steeply enough to bring it, at *dc*, so deep that a vertical shaft to strike it would be an expensive work. If he can secure a surface-claim, covering this triangle as far, for instance, as *d′* and *c′*, he is still further protected. Assuming the vein L to dip 45 degrees, and the width of the claims as shown in Fig. 2 to be the full width of 600 feet, the vein at *d′* and *c′* would be nearly 900 feet vertically below the surface. C would thus possess, practically, the extra-lateral right bounded by *abb′a′*, or a longitudinal extent of the lode increasing with depth. If, however, instead of the case which Mr. Wrinkle supposes, the location of B had the boundaries *hhhh*, it is easy to perceive that C could in no way avoid the cutting off of his claim in depth, by the intersection of *hh′* and *aa′*.

But these and other similar problems are among the simplest, because they assume the apex to be in the line of the true strike—that is, the direction of a horizontal line midway between the walls of the lode—and to be crossed by the end-lines of the location, the side-lines of which would, therefore, be parallel with the strike of the lode. More complicated questions arise when the true course of the lode is curved or crooked, or the outcrop, not being level, is not in the line of strike, or the outcrop or apex crosses one or both of the side-lines.

To take the last condition first, it was the general custom of miners before 1866, that a location held the designated number of feet along the lode, whether the notice and surface monuments correctly showed

* Under the law of 1866, not more than one location could be made on the vein by the same person. There is no such restriction now; and if there were, it could as easily be evaded as formerly, when by the convenient device of locating different claims in the names of friends, and taking immediately quit-claim deeds from them, a man could practically acquire as many feet as he desired. But for the purpose here in view, it might be better that the two claims of C should be in different names until the patents had been issued. It should be added that under the present law a separate discovery is required for each claim.

the strike or not. The miner had the right to "swing his location" and take the full length of his claim, without regard to the claims of subsequent locators. The lode was the main thing located and claimed. Under the law of 1866, it was argued that the same right continued, even after the issue of a patent. The law, it was urged, was intended not to curtail, but to confirm, the rights of miners, and hence patents granted under the law of 1866, or under the law of 1872 on locations previously made, would not confine the patentee to the length of lode actually covered by his surface-lines. The Emma-Illinois case in Utah, and several *nisi prius* decisions on the Pacific slope sustained this view. But it was overturned in Colorado by Judge Thatcher, in the case of *Wolfy and Skinner* v. *the Lebanon Mining Company* (Bell Tunnel—Ben Harding case) reported in 4 Colorado, 112. Carpenter (*Mining Code*, 3d ed., p. 63) gives an abstract, from which the following portions are quoted.

"The evidence tended to show that the Ben Harding lode, in its general course or strike, departed from the vertical side-lines of the location as described in the patent, and entered the Bell Tunnel lode-location, which was also patented. At common law, a grant of land carries with it all that lies beneath the surface to the centre of the earth. This rule, except so far as modified by statute, must extend to the plaintiff's patent. There may be a grant of the mineral, separate from the surface of the earth. The Ben Harding patent must be construed under the act of 1866. . . . . The claimant is required to file in the Land Office a diagram of his vein or lode. This is his own act. Before making such diagram, the law contemplates that he shall so far expose and develop the lode as to be able to trace its course. If the plat made by the surveyor does not cover the lode, he will not be permitted to shift his lines so as to include the lode. The error is his own, not that of the government officer who acts under the direction of the claimant. However tortuous might be the course of the lode, the claimant has a right to follow it up and prepare his diagram so as to include it. There are no words in the act which require the diagram to be in the form of a parallelogram or any other particular form. The act requires that there must be a discovered lode, whose *locus* must be embraced in the limits of the diagram. The surface ground and the lode are not independent grants. It is not the purpose of the law to grant surface-ground without a discovered lode. The lode is the principal thing, and the surface-ground incident thereto.

"In conveying a segment of the earth located under the provisions of the act, it is the intention of Congress to convey a mine contained within that segment as the substance of the grant. The act appeals to the industry of the miner to make sure that the lode is within his location. The higher his diligence the greater his reward. If by lack of care he makes a location not embracing the lode he seeks to secure, he cannot be heard to complain because others have explored and occupied the adjacent territory containing the claim he might have embraced in his diagram. If, as the evidence tends to show, the Bell Tunnel lode is but a continuation of the Ben Harding lode (after its departure from the vertical side-lines), extending through the adjacent location, there is no principle of law or justice, in the absence of an express statutory provision, by which the patentee of the last-named lode can en-

croach upon the premises embraced by the Bell Tunnel lode-location, and deprive the owner thereof of the fruits of his discovery. Before a claimant is entitled to a patent under the act of 1866, he must comply with all its provisions, the leading object of which is to require that the claimant, before applying for a patent, shall ascertain the exact location of his lode and fix by his diagram that location, so that the public may be apprised of its limits and may thereafter with safety explore and occupy adjacent tracts. It is insisted that if not by the terms of the act of 1866, then by virtue of territorial legislation and local customs and rules of miners, the patentee of the Ben Harding lode was entitled to follow the course of the discovered lode beyond its own side-lines, and that the act of 1866 was to recognize and confirm these rules and customs. The act confirmed such legislation of local rules, *so far as the same may not be in conflict with the laws of the United States.* The acts of Congress are paramount to all local laws, and the patentee takes under the laws of the United States. The right of the locator to the possession of his claim and to appropriate to his own use the mineral deposits therein under the acts of Congress, is full and complete, and he need not take steps to obtain patent for the land.

"There is no time prescribed in which he shall apply for the patent. Ample time is given to ascertain the precise *situs* of his lode, with reference to adjacent land. The surface and the lode are both the subject of the grant. The patent operates to convey, not only the circumscribed tract of land, but also the lode contained therein, with the right to follow the same in its downward course into adjoining premises, but not to follow it when in its general strike it departs from the vertical side-lines. In the latter case, after its departure, it is the subject of location by whomsoever it may be discovered. If then, as the evidence tends to show, the ledge on which the Ben Harding lode was located, deflected in its general strike from the patented side-lines, the patentee is not entitled, in virtue of his patent, to its possession beyond the side-lines, as against one who has subsequently located it and patented it."

In the Dives-Pelican and other important cases, Judge Hallett took a similar view. And the whole matter was finally settled by the United States Supreme Court in the Flagstaff case (8 Otto, 463), already cited, from which decision I now quote further:

"Both parties agree that the owner of a mining right in a lode or vein cannot follow the course of the vein beyond the end-lines of his location extended perpendicularly downwards; but that he may follow the dip to an indefinite distance outside of his side-lines. This is undoubtedly the general rule of miner's law, and the true construction of the act of Congress. The language of the act of 1866 (14 Stat., 251) in relation to a 'vein or lode' is, that no 'location hereafter made shall exceed two hundred feet in length *along the vein* for each locator, with an additional claim for discovery to the discoverer of the lode, with the right to follow such vein *to any depth*, with *all its dips, variations and angles*, together with a reasonable quantity of surface for the convenient working of the same as fixed by the local rules, etc.' The act of 1872 is more explicit in its terms, but the intent is undoubtedly the same as it respects end-lines and side-lines and the right to follow the dip outside of the latter. We think that the intent of both statutes is, that mining locations on lodes or veins shall be made thereon lengthwise, in the general direction of such veins or lodes on the surface of the earth where they are discoverable; and that the end-lines are to cross the lode and extend perpendicularly downwards and to be continued in

their own direction either way horizontally; and that the right to follow the dip outside of the side-lines is based on the hypothesis that the direction of these lines corresponds substantially with the course of the lode or vein at its apex on or near the surface. It was not the intent of the law to allow a person to make his location crosswise of a vein so that the side-lines shall cross it and thereby give him the right to follow the strike of the vein outside of his side-lines. That would subvert the whole system sought to be established by the law. If he does locate his claim in that way, his rights must be subordinated to the rights of those who have properly located on the lode. Their right to follow the dip outside of their side-lines cannot be interfered with by him. His right to the lode only extends to so much of the lode as his claim covers. If he has located cross-wise of the lode and his claim is only one hundred feet wide, that one hundred feet is all he has a right to. This we consider to be the law as to locations on lodes or veins.

"The location of the plaintiffs in error is thus laid, across the Titus lode, that is to say, across the course of its apex at or near the surface; and the side-lines of their location are really the end-lines of their claim, considering the direction or course of the lode at the surface.

"As the law stands, we think that the right to follow the dip of the vein is bounded by the end-lines of the claim properly so-called; which lines are those which are crosswise of the general course of the vein on the surface. The Spanish mining law confined the owner of a mine to perpendicular lines on every side; but gave him greater or less width according to the dip of the vein. (See Rockwell, pp. 56–58, and see same book, pp. 274, 275.) But our laws have attempted to establish a rule by which each claim shall be so many feet of the vein, lengthwise of its course, to any depth below the surface, laterally, its inclination shall carry it ever so far from a perpendicular. This rule the court below strove to carry out, and all its rulings seem to have been in accordance with it.

"The plaintiff in error contended, and requested the court to charge, in effect, that having received a patent for 2,600 feet in length and 100 feet in breadth, commencing at the Flagstaff discovery, on the lode at the surface, they were entitled to 2,600 feet of that lode, along its length, although it diverged from the location of their claim, and went off in another direction. We cannot think that this is the intent of the law. It would lead to inextricable confusion. Other locations correctly laid upon the lode, and coming up to that of the plaintiff in error on either side would, by such a rule, be subverted and swept away. Slight deviations of the outcropping lode from the location of the claim would probably not affect the right of the locator to appropriate the continuous vein; but if it should make a material departure from his location, and run off in a different direction, and not return to it, it certainly could not be said that the location was on that lode or vein farther than it continued substantially to correspond with it. Of what use would a location be, for any purpose of defining the rights of parties, if it could be thus made to cover a lode or vein which runs entirely away from it? Though it should happen that the locator, by sinking shafts to a considerable depth, might strike the same vein on its subterranean descent, he ought not to interfere with those who, having properly located along the vein, are pursuing their right to follow the dip in a regular way. So far as he can work upon it, and not interfere with their right, he might probably do so; but no farther. And this consequence would follow irrespective of the priority of the locations. It would depend on the question as to what part of the vein the respective locations properly cover and appropriate."

It will be remembered that the paragraph previously quoted from this decision declares that not the true (horizontal) course of

the vein, but that which is indicated by surface-outcrop or surface-workings, whether level or inclined, is to be followed by the claim. To illustrate: a lode strikes due east and west, and dips 45 degrees south. So long as the outcrop is followed by a level, its course is the true strike. But if, in going eastward, the ground falls away, the course of the outcrop changes from east towards southeast, though the true strike of the lode has not changed. According to the Flagstaff decision, a location on this part of the lode should include the outcrop, and run southeasterly. This rule, and the rule that when the side-lines cross the apex, "they are really the end-lines," are not easily reconciled with the declaration of the court that the rights of a cross-locator, irrespective of priority, are subordinate to those of proper locators, and that the latter rights are, "to follow the dip in a regular way." This matter will be more clearly appreciated after a study of Fig. 3, which is taken, with considerable modification, from a diagram furnished by Chief Justice Beatty of Nevada to the Public Lands Commission (*Report*, p. 403). This figure represents the apex of a lode, ACEBD, dipping as shown by arrows in the rectangles C and D. At *x*, *y*, and *z*, there are croppings upon the surface. The lode is supposed to be perfectly uniform in strike and dip, the true strike being shown by the line OP, which is a horizontal line drawn in the lode. The variations in the course of the apex are due to the topography of the surface, the most violent of them (from C to A) being caused by a precipitous ravine, which cuts through the vein, exposing an outcrop, *z*, in the face of the precipice, while on the other side of the ravine, the outcrop, *w*, shows the continuation of the same vein, unaltered in its true strike and dip.

Between the outcrops *x*, *y*, and *z*, to the left of *x*, and on both sides of *w*, the course of the apex has been determined by shafts and costeaning pits. Upon this lode A, B, C, D, and E have made locations. A, discovering the outcrop *z*, in the ravine, before any other explorations, made the location *aaaa;* B next made the location *bbbb*, upon *x;* then C located *ccc* upon *y;* after which, D, finding the apex with the shaft *s*, and E, finding it with the shaft *t*, made their locations respectively as shown. Now what are the rights of the parties?

Let it be observed that this case has been studiously freed from complications such as occur in most mining lawsuits. There is no controversy as to facts. There is no change of dip or strike, no fault, no indefiniteness of lode or walls, no dispute as to priority,

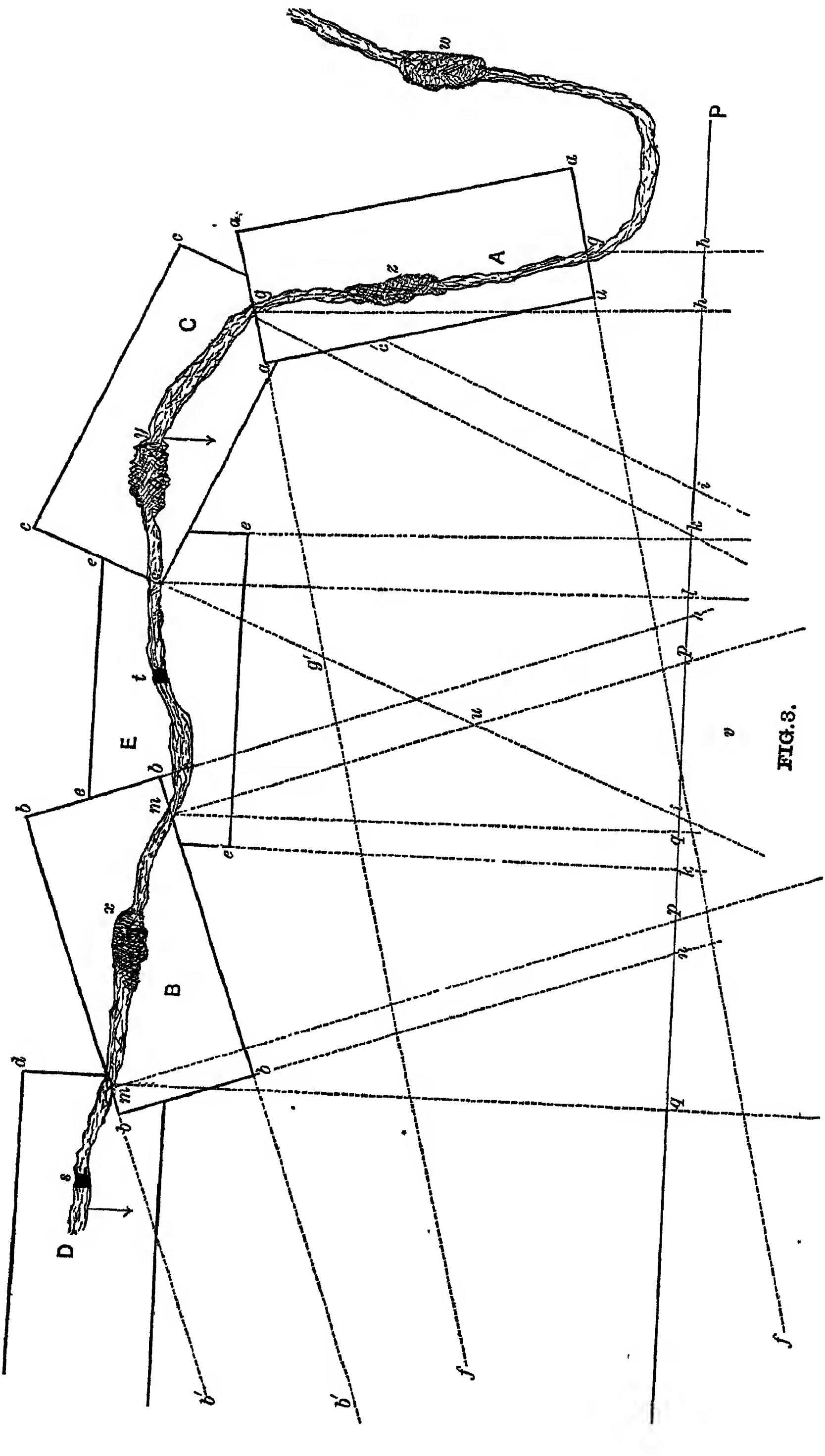

FIG. 3.

no formal defect of title, no peculiar local regulation or custom. A and B, we will suppose, have patents. C, D, and E are indeed subject to reservations of rights of prior locators, covering portions of their claims; but this is a common occurrence, and by no means invalidates the claims, or hinders the obtaining of patents.

According to the views of Judge Beatty, already quoted, E, though locating after B and C (the case of A is not in Judge Beatty's diagram, and is not considered by him), is nevertheless the owner of all that section of the lode included between the lines *mq*, and *cl*, indefinitely prolonged. He asserts that the claims of B and C do not include the top or apex of this section. According to this view, the lines *mq*, *mq*, *cl*, *gh*, *gh*, in the diagram, being the projections of lines drawn *on the true dip* downward from the end of each section of the apex claimed, are the true boundaries of the extra-lateral rights. This, and this only, would be "to follow the dip in a regular way," as the Flagstaff decision puts it. But it is difficult to reconcile this with the explicit declaration of the statute concerning end-lines. The statute does not prescribe any regular way of following the dip. Let us take, for instance, the case of A. He is the first man on the ground. He is, so to speak, an intending purchaser of mineral lands, come at the invitation of the government to look over the unoccupied territory, and decide what piece to buy. No third party is affected by his decision. The statute says to him, "Find a lode, locate a claim not exceeding such a size along the apex, and, having complied with certain forms and conditions, you shall own . . . . all lodes, throughout their entire depth, the top or apex of which lies inside of such surface-lines, extended downward vertically, although they extend, in their course downward, outside the vertical side-lines. But your right of possession to such outside parts shall be confined to such portions thereof as lie between vertical planes drawn downward through the end-lines of your location."

"But how shall I draw my end-lines?" inquires A. "Parallel to each other," replies the statute. "Be sure you draw them across the apex," adds the Supreme Court.

"What is the apex?" he inquires further. The statute is silent; but the Supreme Court says, "That may not always be easy to determine; but one thing is certain. If you follow the outcrop, or the edge of the vein nearest the surface, whether level or inclined, you have got it."

Following these directions, A makes his location *aaaa*, and it is

hard to say why he is not entitled to the section of the lode between the lines *af*, *af*, extended indefinitely. The statute does not hint, and the Flagstaff decision does not clearly imply, that end-lines actually crossing the apex can be objected to as boundaries for the extra-lateral right. Nor can B, C, D, and E complain. They have not yet arrived. When they do arrive, they must take what is left. Their rights, whatever they may be, will stop at the upper line *af*, and recommence at the lower line *af*. We have thus the remarkable proposition, that of the point *u* in the lode, A is the owner, by virtue of the apex in his claim, while, of the point *v*, directly below it on the dip, B is the owner, by virtue of the apex in his claim. And continuing down in the same line, a point would at last be reached, below all the rights of A, B, C, and belonging to E. This is an absurd result, and doubtless was not contemplated by the makers of the law. Yet how can it be avoided? There seems to be but one possible way. The courts may say to A, "The extra-lateral right granted to you was based on the condition that the lode in its course downward, extended outside your side-line. Now this course downward must be taken on the true dip. You can not follow the lode in the direction of your end-lines in this case, if you thereby interfere with other, even later, locators, who are following the dip in a regular way." If this be a permissible construction of the law, Judge Beatty's view would be sustained; and A, who located, as he supposed, a length, *gg*, of the lode, would find his real length reduced to *hh*. And there would be other results. The uniform ruling of the courts as to end-lines would be overthrown, and the "iron-clad potency" of United States patents would be sadly impaired. Turning back, for instance, to Fig. 2, we may see that the location *bbbb* has end-lines obliquely crossing the apex. Thousands of mining claims have this form; and the extra-lateral right, bounded by *bb'*, *bb'*, has been maintained in innumerable instances. To demand that this right shall follow the true dip would make the definition of the right difficult, in many cases, in the early stages of exploration. It might not be impracticable to require that the course of a lode should be horizontally determined, and that end-lines of locations should be drawn at right angles to this course, though there would be endless trouble from local variations in dip and strike. But the present question is whether the statute does make such a requirement. Judging from universal practice under it, it does not. Miners have a special reason for drawing oblique end-lines. The valuable ore in our gold

and silver lodes generally occurs in shoots or chimneys, which pitch obliquely in the lode; and a skilful prospector endeavors to make his location so that he will have the right to follow not merely the lode, but the pay-shoot in the lode, beyond his side-lines. To overrule this practice would be a policy both novel and questionable.

Returning to Fig. 3, then, we see that either construction of the law as applied to the case of A involves great difficulty. A case involving this principle is now on trial in Dakota before Judge Church.

The location of B, in this diagram, presents even greater perplexity. For the lode passes under the side-lines of B at *mm;* and according to the Flagstaff decision, he cannot claim the boundaries *bn, bn.* Either (1) in the words of that decision, "the side-lines of his location are really the end-lines of his claim"—in which case his extra-lateral boundaries are *bb′, bb′* (to the consternation of D!); or (2) the true end-lines of his claim are to be drawn through *m m,* parallel to the end-lines of his survey—which would give the boundaries *mp, mp;* or (3) the new end-lines are to be drawn on the true dip, in which case we have *mq, mq.* In the first case the triangular space *qnb′* is left unappropriated and without an apex, unless the claim of A takes part of it; and E will have the triangle inclosed between *ek* and *ci.* In the second case, the claim of E is practically reduced to the triangle *muc;* and in the third case, E will have the triangle inclosed between *mq* and *ci′* continued till they intersect—subject, in both cases, to the possible superior claims of A. And in all cases, E will, at some depth, come into his full right to the distance *ql* along the lode. It may even be that E, at a depth below the lines *mp, gk,* or *ci* and *af* (produced to cross his ground), that is to say, below the ground covered by the claims of either or all of A, B, and C, may rightfully own the length *kk* of the lode. For, it will be noted, the lode does not leave his location at *m* and *c;* his location is simply overlapped by B and C; and where their subterranean rights end, it is conceivable that his may begin again.

The same is true of the location of C. If the extra-lateral rights of A are bounded by *af, af,* then C is confined to the triangular space *gycg′;* but below the lower line *af,* he might recover his full right to the distance *ii* on the lode (that is, if it were not for the prior claim of B, which, however, at a greater depth, would likewise get out of his way). This distance *ii,* by the way, covers a length upon the lode greater than that of C's surface claim.

This discussion might be indefinitely prolonged by introducing into the problem such irregularities of the vein-formation as perplex experts, lawyers, judges, and juries in nearly all mining suits. But it is sufficient to show what difficulties beset cases which might be considered exceptionally simple.

A further complication of the end-line question remains, however, to be considered. The act of 1872 makes no explicit distinction, as to the extra-lateral right, between the lode first discovered and used as a basis for the location and other lodes cropping or topping in the same location. It seems to have imagined that these lodes would all be parallel to the first discovered, and that the same end-lines would do for them all. This is, indeed, the view taken by Judge Elbert in *Paterson* v. *Hitchcock* (Bull of the Woods—American case, 3 Colorado, 533) from the abstract of whose decision in Carpenter's *Mining Code* (3d ed., p. 61) I quote the following extract:

"Under this act [1866] the right to surface-ground was clearly dependent upon the right to the lode located. It failing, all incidents thereto attaching would necessarily fail. Although the act of 1872 enlarges the rights of the locator by a grant of all the veins, lodes, and ledges the top or apex of which lies within his surface-lines, we are still of the opinion that his right to the surface-ground continues dependent upon his right to the principal lode, and that his right to other lodes within his surface-limits is equally dependent. This enlargement of the rights of the locator was doubtless intended to stimulate his enterprise by increasing his reward; but the controlling reason was to prevent the controversies which were constantly arising respecting veins or lodes connected or associated with the lode claimed. These controversies abstracted from the full and proper enjoyment of the principal lode granted, and the design was to settle and prevent them. In this, and in the case of surface-ground, it was intended to grant that which was associated with the principal lode by proximity, within prescribed limits. When this association ceases in the case of surface-ground, the reason for granting it ceases. A mineral vein or lode, is a leading term in both acts. There must be a lode discovered and appropriated by compliance with the requisites of location.

"This is the prominent and pronounced subject of the grant. This is what the miner has discovered, and claimed by right of discovery. The security of his title thereto, was the practical necessity with which the act dealt; all else, we think, incident thereto: under the act of 1866, the right to the surface-ground; under the act of 1872, both the right to the surface-ground and the right to other veins, lodes, and ledges. The principal lode constitutes the measure of the miner's right to the surface-ground, *as the surface-ground, when thus determined, in turn constitutes the measure of his right to other veins, lodes, and ledges,* subject to the express limitations of the law. It follows, therefore, that if the lode located terminates at any point within the location, or departs at any point from the side-lines, that the location beyond such point, and to that extent, is defeasible, if not void."

I have italicized the most important clause in this opinion. The main point aimed at by the court is the "side-line question" (sub-

sequently settled in the Flagstaff case); but incidentally the application of the end-lines to the "other lodes" is defined.

Fig. 4 illustrates the effect of this ruling. Upon the lode LL, dipping as shown by the arrow, the location *abcd* has been properly made. It covers the apex throughout, and the end-lines are at right angles to the true as well as the apparent course of the lode. There can be no doubt, therefore, that the locator owns this lode beyond the side-line *cd*, between the boundaries *de* and *cf*. A second lode, V, not discovered at the time of location, crosses the lode L, with

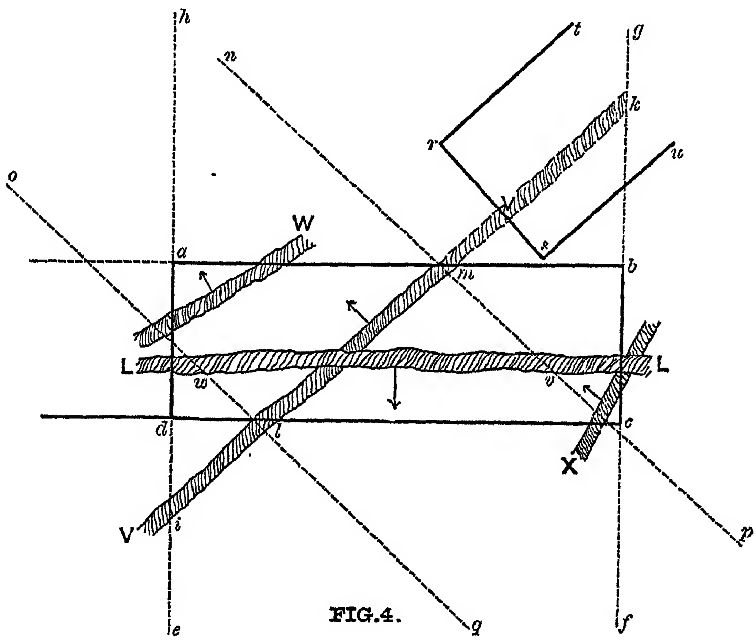

FIG. 4.

the dip shown by the arrow. What are the rights of the locator of L upon this lode V? According to Judge Elbert's ruling, the lines *eh* and *fg*, projections of the vertical planes through the end-lines of the L location represent the boundaries of the extra-lateral right on V. That is to say, the locator, whose surface includes only the length *lm* of this vein, will own the length *ik* upon it at all depths —even though a subsequent locator should have made the location *trsu* upon V as his main lode. Nay, we may even assume that the existence of V was not known until it was discovered and located in *trsu*, and that thereupon the prior locator of L, finding that the new vein ran through his ground, stretched out his end-lines after it. If the above ruling is correct, the locator of L would get V as far as *k*. And this seems to be the best construction of the law.

For if it should be held that the locator could own only so much of V as his surface contains of its apex, then *mn*, *lo* would be his boundaries, and we should have two entirely distinct sets of boundaries under one location. I forbear to discuss the aggravations which would be effected by the further discovery of the lodes W and X, each of which crosses one of the L end-lines.

If, on the other hand, the vein V had been the one located and L had afterwards been discovered within the claim, then *mn*, *lo* (or, on another theory, *ma*, *ld*) would be the boundaries of the V-claim underground, and *mp*, *wq*, those of the L-claim. That is to say, this would be the case according to one solution of the problem considered in connection with B's claim, Fig. 3. Whoever is fond of permutations and combinations may find amusement in combining the conditions of Figs. 3 and 4 indefinitely. I will suggest but one further example:

In Fig. 3, let us suppose that other locations are made beyond A, from *g* to *w*, etc., following the curve caused by the ravine in the outcrop. The decision as to the rights of such locations is not easy, however their end-lines be drawn. It is now pending in the United States Supreme Court in the case of the *Iron Silver Mining Company* v. *the Elgin Mining Company* (Stone—Gilt Edge case). The court in Colorado has decided that claims located on the sides of such a bend, following as they do more nearly the dip than the strike of the lode, get no extra-lateral rights at all. The Supreme Court, if it overrules this, will have to decide what are the rights of such locators—and this will settle the problem of A, Fig. 3.

There are many other sources of doubt and difficulty in the United States mining law. Even the four topics of the lode, the apex, the downward course, and the end-lines have not been exhausted in the present paper. But I trust enough has been said to show that the law of the apex is no great improvement on the old law of the discoverer, and that the law of the surface-owner—or the so-called "square location," if it could only be made acceptable to our mining districts, would deliver the industry from much trouble and expense. Failing that, we must simply look to the courts for a gradual settlement, though it be arbitrary and questionable *per se*, of the embarrassing questions that surround the subject. Any decision would be better than the present confusion.

It remains only to mention a very important decision, rendered June 18th, 1883, by which the meaning of the terms "known lode,"

in section 2333 of the Revised Statutes, has been determined. The case was that of *The Iron Silver Mining Company* v. *Sullivan et al.* The section referred to (already quoted in this paper) provides for the reservation from any placer-patent of a known lode within the placer-survey; but declares that "when the existence of a vein or lode is not known, a patent for the placer-claim shall convey all valuable mineral and other deposits within the boundaries thereof." It must also be remembered that section 2329 includes under "placers," all forms of deposit excepting veins of quartz or other rock in place.

In the case referred to, the plaintiff brought suit against parties working lode-claims upon its patented placer-ground. A clause in the placer-patent excepts from the grant thereof all lodes known to exist within the claim at the date of the application. The defendants claimed that their lode was so known to exist, by reason of developments made in neighboring claims; but it was conceded that no location had been made upon it, within the placer-claim, before the application for placer-patent.

Upon these pleadings, Judge McCrary held, in the United States Court at Denver, that the terms "known to exist," and equivalent phrases in section 2333, mean a claim duly located or recorded and owned by a third party before the placer-claimant applied to the government for a patent. The mere existence of a lode by geological inference, or by general rumor and belief, will not suffice. It must be actually known by discovery, and legal proceedings (at least to the extent of record) based thereon.

This decision is said to have been appealed to the Supreme Court. It is difficult to see how it can be set aside. If sustained, it opens a curious suggestion to miners. Under it, it will be only necessary for a prospector who has discovered ore in an unoccupied locality, to avoid carefully such developments as would demonstrate the existence of a lode in place, and to make prompt application for a placer-patent; after which application he may proceed to find as many lodes as he can: they will all belong to him, and he will have 160 acres, instead of about 20, as his maximum surface area, and will pay $2.50, instead of $5, per acre. Extra-lateral rights he will have none; but in view of the large area granted, he can afford to go without them. It appears, therefore, that even under the present law, valid "square locations" can be made, covering lodes; and that they will be of greater size than would probably be granted by an

explicit and intentional "square location" law. This is only one more instance of the way in which our present statutes may operate to bring about results not contemplated by Congress; and it constitutes an additional reason for the authoritative construction of the law by the Supreme Court, or its radical reconstruction at the hands of Congress.

PROCEEDINGS

OF THE

ANNUAL MEETING IN CINCINNATI.

FEBRUARY, 1884.

ANNUAL MEETING IN CINCINNATI.

COMMITTEES.

Local Committee of Arrangements.

L. E. Warner, *Chairman;* J. B. Porter, *Secretary.*

Committee of Organization.

L. E. Warner, Matthew Addy, and Colonel L. M. Dayton.

General Committee.

Mayor Thomas J. Stephens, Julius Dexter, W. S. Groesbeck, John Carlisle, D. J. Fallis, W. J. Breed, H. Mulhauser, George Moerlein, William P. Anderson, Thomas G. Smith, Jacob Traber, General H. M. Cist, Captain A. Q. Ross, Alexander McDonald, Aaron F. Perry, Judge Patrick Mallon, E. F. Noyes, George Ward Nichols, A. D. Bullock, H. Duhme, E S. Wayne, John Mitchell, R. Dykens, Albert J Redway, H. P. Lloyd, Matthew Addy, Colonel L. M. Dayton, John Scott, E. F. Fuller, J. H. Stewart, M. E. Ingalls, W. W. Peabody, W. B. Shattuc, W. L. O'Brien, E. P. Wilson, H. J. Page, C. C. Cobb, H. H. Tatem, John Egan, Brent Arnold, J. E. Rose, A. Griggs, D. Edwards, W. J. M Gordon, Edwin Stevens, W. L. Robinson, B. E. Hopkins, C. W. Withenbury, H. Jenny, A B. Merriam, H. DeBus, Armor Smith, Jr., C. O. Lockard, Colonel W. E. Merrill, E L. Harper, A. G. Moore, Alexander Hill, W. H Taft, Percy Procter, W. J. Lampton, Rev. D. W. Rhodes, W. H. Miller, G. P. Wilshire, W. L. Davis, C. L. Mudge, William H. H. Laws, Oliver Kinsey, W. A. Rogers, Archer Brown, F. W. Handy, C. W. Merrill, Frank Beresford, Dr. John Wiggins, H. J. Groesbeck, Telford Groesbeck, Harvey Tilden, Colonel A. L. Anderson, G. Bouscaren, H. J. Stanley, A. G. Wetherby, Frederick G. Roelker, Dr. A. A. Springer, Dr. W. L Dudley, W. A. Collord, L. M. Hosea, M. D. Burke, L. S. Cotton, D. L. James, R. M. Byrnes, A C. Nash, George W. Rapp, Charles Crapsey, James W. McLaughlin, Peter G. Thomson, James F. Shumate, Samuel Stevenson, J. H. Garrison, Charles Kebler, Dr. Frederick Roeder, Elliot A. Kebler, P. G. March, P. B. Warner, Professor J. B. Peaslee, Professor Thomas Vickers, Professor H. T. Eddy, Professor Thomas French, Jr., Professor T. H. Norton, Professor E. W. Hyde, Captain J. A. Robinson, Florence Marmet, S. F. Dana, S. P. Kineon, T. B. Collier, P. R. Budd, William Galway, T. H. Aldrich, W. F. Aldrich, Colonel C. Cadle, Jr., Charles L. Rogers, A. Pluemer, Nelson W. Perry, J. B. Porter, C. B. Going, L. E. Warner.

The General Committee was divided into sub-committees of Local Arrangements, Reception, Ohio Mechanics' Institute, Cincinnati

University, Society of Natural History, Cincinnati Chapter of Architects, Order of Cincinnatus, Finance, and Transportation.

The opening session was held in Greenwood Hall, by invitation of the Ohio Mechanics' Institute.

Mr. L. E. Warner, Chairman of the Local Committee, introduced Mr. John D. Banks, who appeared as the representative of Mayor Stephens, and extended to the Institute, on behalf of the city authorities, a cordial welcome, despite the unfavorable circumstances which might interfere with the entertainment Cincinnati would have been glad to offer. Mr. Banks's earnest remarks were received with applause.

Professor H. T. Eddy, who occupies the chair of mathematics and civil engineering in the University of Cincinnati, followed with a special and fraternal welcome from that institution, together with the Ohio Mechanics' Institute, the Society of Natural History, the Cincinnati Chapter of Architects, the Order of Cincinnatus, and the educational institutions of the city generally, the sympathy of which with the purposes of the Institute, and their pleasure at its presence among them, he gracefully expressed.

Ex-Governor J. D. Cox then addressed the Institute in the name of the citizens of Cincinnati at large, eloquently describing the advantages which all classes must derive from such pursuits as those of the members before him, and congratulating them upon the great power for good which they had acquired, by calling to their aid the principle of associated effort.

President Hunt replied for the Institute, paying a warm tribute to the greatness of Cincinnati, especially in such times of trouble and anxiety as the existing flood of the Ohio had produced.

A paper was then read by Arthur V. Abbott, of New York city, on Improvements in Methods of Physical Tests.

The President appointed Messrs. David Williams, S. T. Wellman, and J. F. Lewis, scrutineers, to examine the ballots for officers of the Institute, and report at a subsequent session.

At the second session on Wednesday morning in Greenwood Hall, the Secretary read the following papers:

Sulphur Determinations in Steel, by Magnus Troilius, of Nicetown, Philadelphia.

Tables for Facilitating the Heat Calculations of Furnace Gases containing CO_2, CO, CH_4, H and N, by Magnus Troilius, of Nicetown, Philadelphia.

Further Determinations of Manganese in Spiegel, by G. C. Stone, of Newark, N. J., and

The Apatite Deposits of Canada, by Dr. T. Sterry Hunt, of Montreal, Canada.

A Preliminary Announcement of a New Mineral, was then read by N. W. Perry, of Cincinnati, and discussed.

Mr. Perry also exhibited a curious piece of insect-weaving which he had brought from Mexico.

The Secretary then read a Note Concerning Certain Incrustations on Pig Iron, by Kenneth Robertson, of Jersey City, N. J., and Frank Firmstone, of Easton, Pa.

The next paper was on the United States Test Commission Bill, by Dr. T. Egleston, of New York city; after which the Secretary read a Note on the Determination of Phosphorus in Iron, by Frank Julian, of Iron Mountain, Mich., and a Note on Tamping Drill Holes with Plaster of Paris, by Frank Firmstone, of Easton, Pa.

The President, before adjournment, read an invitation from Mrs. Longworth to the members of the Institute to visit the potteries and their warerooms.

The third session was held at Greenwood Hall on Wednesday afternoon. The following papers were read and discussed.

A Grade of Pig Iron made from Carbonate Ore, by Edward Gridley, of Wassaic, N. Y. (Read by the Secretary.)

Improvements in Coal Washing Machinery, Elevators, and Conveyers, by S. Stutz, of Pittsburgh, Pa. (Read by the Secretary, and the diagrams explained by the author.)

Notes on Lithia in Fire-clay, and on An Excess of Phosphorus in Pig Iron, by Professor N. W. Lord, of the Ohio State University, Columbus, O.

The Beneficiary Fund of the Lehigh Coal and Navigation Company, by Joseph S. Harris, of Philadelphia. (Read by the Secretary, and followed by discussion, during which the Secretary read a communication on this subject from F. Z. Schellenberg, Irwin Station, Pa.)

The use of natural gas at the Edgar Thomson Steel Works was described by W. R. Jones, of Pittsburgh.

The President read an invitation from the Young Men's Christian Association of Cincinnati to the members and their friends to visit the rooms of the Association during the meeting.

The final session was held on Thursday morning in the small hall of the Ohio Mechanics' Institute, when the following papers were read:

When was Coke Pig Iron first made at Coalbrookdale? by J. D. Weeks, of Pittsburgh.

Remarks on Torsion, by Dr. Alfred Springer, of Cincinnati.

The Fusion and Plating of Iridium, by Professor W. L. Dudley, of Cincinnati.

Analyses and Tests of Steel, by P. G. Salom, of Thurlow, Pa. After some remarks in discussion, on motion of Dr. T. Egleston, seconded by Mr. William Kent, the further discussion of this paper was postponed until the next meeting, to be then made the special order for one of the sessions.

On motion of Dr. Egleston, seconded by Mr. E. C. Pechin, it was voted that a committee be appointed by the President to consider and report upon the conditions of uniformity in physical tests, particularly as to the uniform dimensions of test-pieces.

President Hunt said this committee would be appointed and announced by the incoming President.*

At this session was read a communication from the Secretary of the Chamber of Commerce of Cincinnati extending the freedom of the floor of the chamber to the members of the Institute during their stay in the city; also an invitation from the Art Union to visit the Cincinnati Art Museum.

The following papers were read by title:

A Silver Amalgamation Mill, by W. H. H. Bowers, of New York city.

A Process for Making Iron Direct from the Ore, by Willard P. Ward, of New York city.

The Pyrites of Louisa County, Va., by W. H. Adams, of New York city.

The Crooked Fork Coal-field of Morgan County, Tenn., by Henry E. Colton, of Nashville, Tenn.

The Stratigraphical Order of the Lower Coal Measures of Ohio, by Professor Edward Orton, of Columbus, Ohio.

The Distribution of High-Pressure Steam in Cities, by William P. Shinn, of New York city.

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* President Bayles has since appointed the following committee: Prof. Thos. Egleston, Chairman, and Messrs. T. C. Clarke, A. P. Boller, E. D. Leavitt, Jr., and A. F. Hill.

The Quemahoning Coal-field of Somerset County, Pa., by Dr. J. P. Kimball, Lehigh University, Bethlehem, Pa.

Certain Silver and Iron Mines in the States of Coahuila and Nuevo Leon, Mexico, by Dr. Persifor Frazer, of Philadelphia.

Notes on some Iron Ore Deposits of Pitkin County, Colorado, by W. B. Devereux, of Aspen, Col.

The Iron Ores of Alabama, Georgia, and Tennessee, by Professor J. B. Porter, Cincinnati, O.

Biographical Notice of C. W. Siemens, by George W. Maynard, of New York city.

The Secretary read the following:

Report of the Council.

In accordance with the rules, the Council makes the following report to the Institute:

The financial statement of the Secretary and Treasurer, duly audited, shows receipts for the year from all sources of $17,598.25, and expenditures of $13,886.29, leaving a surplus for the year of $3711.96.

Since the balance of the last annual statement was $5028.52, and $4961 have been invested during the year in United States bonds, the actual surplus of receipts over expenditures for the year, is $3644.44.

The detailed statement is as follows:

Statement of the Secretary and Treasurer, of Receipts and Disbursements from February 1*st,* 1883, *to January* 31*st,* 1884.

Dr.

Balance at last statement,	$5,028 52	
Received for dues from members and associates,	10,666 00	
" for life-memberships,	500 00	
" from sale of publications,	559 75	
" for binding *Transactions*, and Index,	431 55	
" for authors' pamphlets,	128 50	
" for electrotypes,	27 55	
Interest on United States bonds,	184 50	
Interest on deposits,	71 88	
		$17,598 25

Cr.

Paid for printing vol. xi. *Transactions*,	$1,397 77	
" binding vol. xi. *Transactions*,	456 00	
" printing pamphlet editions of papers,	933 40	
" " author's editions of papers,	210 05	
" " list of members,	37 50	
" " mailing list,	60 00	
" " circulars, etc.,	100 25	
" binding exchanges,	35 00	
" engraving and lithographing,	924 75	
" electrotyping,	62 70	
" postage,	572 60	
" freight, expressage, duty, etc,	52 62	
" stationery (post-paid) (letter-press),	39 30	
" telegrams,	22 34	
" insurance,	36 14	
" rent of office,	120 00	
" storage of *Transactions*,	37 50	
Secretary's salary,	2,625 00	
Secretary's assistant's salary,	1,000 00	
Expenses of Secretary and assistant at meetings,	202 37	
4400 United States 4½ per cent. bonds,	4,961 00	
		$13,886 29
Excess of receipts over expenditures,		$3,711 96

The eleventh volume of *Transactions* has been issued, and is now in process of distribution. The Index to vols. i. to x., inclusive, is still in the printer's hands, and will be issued and distributed at an early day.

Three meetings have been held during the year: the annual meeting of 1883 in Boston, a summer meeting at Roanoke, Va., and an autumn meeting at Troy, N. Y. Professionally as well as socially these meetings were highly successful, and the Institute is to be congratulated upon the evidences of increasing prosperity which both its meetings and its *Transactions* furnish.

There were elected at the three meetings mentioned, 135 members and 36 associates. During the year 17 members have resigned and 26 have been dropped from the rolls for non-payment of dues.

The list of deaths comprises 2 honorary members, C. William Siemens and L. Gruner, and 10 members, J. B. Brinsmade, J. B. Converse, R. T. J. De Peiger, John Griffen, James F. Hall, Francis A. Lowe, William Manthey, James Park, Jr., Raymundo de Santa Maria, Charles Schuchard.

The membership of the Institute now comprises 3 honorary members, 50 foreign members, 1134 members, and 154 associates, a total of 1341.

The Council received with regret, at the close of the year 1883, the resignation of the Secretary of the Institute, Dr. T. M. Drown, who was forced by the pressure of private affairs to retire from this position after years of faithful and skilful service. As a testimony of the esteem and gratitude of the Institute, but not less in recognition of the professional eminence of Dr. Drown, and of the great benefit which his labors have conferred upon a most important department of metallurgy, viz., the development of rapid, convenient and accurate methods of chemical analysis; and in recognition also of the important part which Dr. Drown has taken in extending among American works the practical application of chemical tests and methods, the Council recommends that Dr. Drown be elected an honorary member of the Institute. The proposal of his name for such election has been signed by 15 members, in accordance with the rules, but the Council does not doubt that each and every member of the Institute would have been equally willing to sign such a proposal.

Dr. T. M. Drown was thereupon balloted for as an honorary member of the Institute, and was unanimously elected. The announcement was received with enthusiastic applause.

The following gentlemen, proposed for election as members and associates and recommended by the Council, were elected:

MEMBERS.

Robert H Aiken,	Butte City, Montana.
J. N. Barr,	Milwaukee, Wis.
Carl Barus,	New Haven, Conn.
Francis H. Blake,	Silver King, Arizona.
W. H. H. Bowers,	New York City.
Jerome L. Boyer,	Columbia, Pa.
John C. Branner,	Scranton, Pa.
Cabell Breckenridge,	Covington, Ky.
Walter Lee Brown,	Chicago, Ill.
John Parke Channing,	New York City.
W. D. Church,	Topeka, Kansas.
Thomas Crowe,	South Chicago, Ills.
Louis M. Davis,	Ciudad Bolivar, Venezuela.
Albert de Deken,	Braddock, Pa.
W. L. Dudley,	Cincinnati, O.
Frank C. Earle,	Tombstone, Arizona.
Edward H. Earnshaw,	Riverton, N. J.
Henry S. Eckert,	Reading, Pa.

Isaac Eckert,	Topton, Pa.
F. A. Emmerton,	Joliet, Ill.
Charles W. Eoff,	Wheeling, W. Va.
R. J. Frechville,	Truro, Cornwall, England.
William Frechville,	Hoover Hill, N. C.
Homer T. Fuller,	Worcester, Mass.
Sampson W. George,	Chester, N. J.
Alexander Gordon,	Hamilton, O.
Charles Weed Gray,	Johnstown, Pa.
O. D. Harris,	Ste. Genevieve, Mo.
Ottakar Hofmann,	San Francisco, Cal.
Ferdinand Howald,	Caperton, W. Va.
John T. Jeter,	Wilkesbarre, Pa.
William M. Kaufman,	Reading, Pa.
Eliot A. Kebler,	Newport, Ky.
Waldeman Lindgren,	Newport, R. I.
Jawood Lukens,	East Conshohocken, Pa.
Henry Martin,	Rosita, Col.
J. R. Maxwell,	Cincinnati, O.
H N. Pierce,	Chaffee, Col.
Robert E. Plumb,	Detroit, Mich.
C. S. Rea,	Columbus. O.
Charles E Ronaldson,	Philadelphia.
E. H. Russell,	Park City, Utah.
William Saint,	Porth, South Wales.
Morris Sellers,	Chicago, Ill.
Richard C. Shaw,	Tombstone, Arizona.
Oberlin Smith,	Bridgeton, N. J.
Alfred Springer,	Cincinnati, O.
Victor O. Strobel,	Pittsburgh, Pa.
Theodore Tonnele,	McKeesport, Pa.
T. B. Walker,	Ashland, Ky.
Philip Wallis,	Aurora, Ill.
Albert G. Wetherby,	Cincinnati, O.
N. B. Wittman,	Pittsburgh, Pa.
W. H. Woodward,	Wheeling, W. Va.

ASSOCIATES.

G. T. Barus,	Philadelphia.
Frank Beresford,	Cincinnati, O.
John Crerar, Jr.,	Chicago, Ill.
L. M. Dayton,	Cincinnati, O.
Frank Enos,	Brooklyn, N. Y.
Henry A. Keith,	Chicago, Ill.
John Francis LeBaron,	Jacksonville, Florida.
Maurice J. Lunn,	Pittsburgh, Pa.

The status of the following associates was changed to membership: Floyd Davis, Leon P. Fenstman, and Arthur Thacher.

The following resolutions were adopted amid general applause:

Resolved, That the heartfelt thanks of the American Institute of Mining Engineers are tendered to the Cincinnati Railway Club, the Ohio Mechanics' Institute, the Cincinnati Art Museum, the Society of Natural History, the Cincinnati Chapter of Architects, the University of Cincinnati, the Cincinnati, New Orleans and Texas Railway, the Cincinnati Chamber of Commerce, the Order of Cincinnatus, the Cincinnati Young Men's Christian Association, the General Committee of citizens, and the various sub-committees; to Mrs. Longworth, Mrs. George Ward Nichols, and Mrs. T. H. Aldrich; to the enthusiastic and indomitable local committee of our own members, and to the citizens of Cincinnati generally and the Cincinnati ladies particularly, for the cordial hospitality which they have extended to the Institute under circumstances of so much difficulty and inconvenience, and for the admirable energy and skill with which, in spite of every obstacle, arrangements have been carried out, rendering this meeting delightful and memorable.

Resolved, That besides and beyond the professional and social interest which would at any time characterize a visit to this great and beautiful city, the members of the Institute especially prize the opportunity which has been afforded them, of witnessing the noble example of heroic courage, cheerfulness, hope, patience, and generosity in the presence of widespread calamity, exhibited by Cincinnati.

The Scrutineers appointed at the first session of the meeting, presented their report, through Mr. David Williams, chairman, declaring the following persons elected officers of the Institute:

PRESIDENT.

James C. Bayles, ... New York City.

VICE-PRESIDENTS.

(To serve until February, 1886.)

Eckley B. Coxe, ... Drifton, Pa.
Thomas Egleston, ... New York City.
Edmund C. Pechin, ... Cleveland, O.

MANAGERS.

(To serve until February, 1887.)

Edgar S. Cook, ... Pottstown, Pa.
Frank Firmstone, ... Easton, Pa.
G. W. Maynard, ... New York City.

TREASURER.

Theodore D. Rand, ... Philadelphia.

SECRETARY.

Rossiter W. Raymond, ... New York City.

Mr. R. W. Hunt, the retiring President of the Institute, before declaring the meeting adjourned, spoke warm words of farewell to the members of the Institute, thanking them for their forbearance and hearty co-operation, which had made his term of office one of the pleasantest years of his life. He then extended a cordial greet-

ing to his successor, with many kind wishes for a like happy administration.

On Thursday evening the members and ladies accompanying them were charmingly entertained by Mr. and Mrs. T. H. Aldrich at a reception at their house at Mt. Auburn, at which many citizens of Cincinnati were present.

On Friday morning a party of members and friends was taken by special train, provided by the courtesy of the Cincinnati, New Orleans and Texas Railway Company, to High Bridge, Kentucky. After inspecting the bridge and enjoying the scenery, the party was served with lunch in the open air and returned to Cincinnati in time to attend, as guests of the Local Committee, one of the performances of the Grand Opera Festival in Music Hall.

The following members and associates made their presence at the meeting known to the Secretary:

A. V. Abbott.
T. H. Aldrich.
C. M. Atkins, Jr.
W. S. Ayres.
James C. Bayles.
T. Beresford.
W. F. Biddle.
G. Billing.
Cabell Breckenridge.
P. H. Brown.
S. M. Buck.
M. C. Bullock.
M. D. Burke.
C. Constable.
F. P. Davis.
Floyd Davis.
L. M. Dayton.
Hunter Eckert.
Thomas Egleston.
S. F. Emmons.
J. W. Farquhar.
J. C. Ferris.
R. Forsyth.
C. B. Going.
Alexander Gordon.
F. W. Gordon.
E. C. Hegeler.
F. A. Hill.
J. F. Holloway.
H. A. Hunicke.
R. W. Hunt.
W. R. Jones.
E. A. Kebler.
William Kent.
Charles Kirchhoff, Jr.
J. S. Lane.
J. F. Lewis.
William Lilly.
Maurice J. Lunn.
P. N. Moore.
W. B. Page.
I. P. Pardee.
E. C. Pechin.
N. W. Perry.
J. C. Platt, Jr.
A. Pluemer.
R. E. Plumb.
J. B. Porter.
W. B. Potter.
R. W. Raymond.
Pedro G. Salom.
H. S. Smith.
Alfred Springer.
S. Stutz.
C. O. Thompson.
L. E. Warner.
J. D. Weeks.
S. T. Wellman.
A. G. Wethersby.
S. Whinery.
David Williams.
J. P. Witherow.

PAPERS

OF THE

CINCINNATI MEETING.

FEBRUARY, 1884.

THE APATITE DEPOSITS OF CANADA.

BY T. STERRY HUNT, LL.D., F.R.S., MONTREAL, CANADA.

THE presence of apatite in the Laurentian rocks of North America has long been known to mineralogists, and within a few years so much interest has been excited by the economic importance of deposits of this mineral found in certain parts of Canada, that a brief history of our knowledge of these deposits may not be unacceptable to the members of the American Institute of Mining Engineers. It was in 1847 that the present writer was shown by a local collector of minerals some large crystals, which had been called beryl, found in North Burgess, in Ontario. These were at once recognized as apatite; and after a visit to the locality, this was described in the report of the geological survey of Canada for that year as likely to furnish an abundant supply of a valuable fertilizer; the opinion being then expressed that the fact of "the existence of such deposits as these will prove of great importance."

Specimens of apatite from this locality, collected by the writer, were shown among the economic minerals of Canada at the great exhibitions of London and Paris in 1851 and 1855, and the mineral had already been found by explorers at several other points in the same region previous to 1863. In the *Geology of Canada*, published in that year, the writer resumed the results of his further studies of these deposits, and described the apatite as occurring in the Laurentian rocks, both distributed in crystals through carbonate of lime, and in "irregular beds running with the stratification and composed of nearly pure crystalline phosphate of lime." This was further said to occur in North Burgess, in several parallel "beds interstratified with the gneiss."*

In a subsequent report of the geological survey, in 1866, I again noticed the occurrence of the apatite in beds in the pyroxenic rocks often found associated with the gneiss. It was said, "the presence of apatite seemed characteristic of the interstratified pyroxenic rocks

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Loc. cit., pp. 592, 761.

of this section, in which it was very frequently found in small grains and masses, alike in the granular and the micaceous schistose varieties." In these rocks, the apatite was said to mark the stratification, and to form, in one example, a bed, in some parts two feet thick, which was traced 250 feet along the strike of the pyroxenic rock. I at the same time described the occurrence of apatite, often with calcite, in "true vein-stones, cutting the bedded rocks of the country;" alike gneiss, pyroxenite, and crystalline limestone. These latter deposits were farther spoken of as well-defined veins, traversing vertically, and nearly at right angles, the various rocks; as often banded in structure, and including besides apatite both calcite and mica, occasionally with pyroxene, and more rarely with hornblende, wollastonite, zircon, quartz, and orthoclase. These veins were said to be very irregular, often changing rapidly in their course from a width of several feet to narrow fissures. It was added, "it is evident that this district can be made to supply considerable quantities of apatite;" and while the uncertainties arising from the irregularities of the veins were mentioned, it was said, that "some of the deposits might probably be mined with profit."*

Before following farther this history, it may be stated that there are two districts in Canada which have, within the past few years, been found to contain deposits of apatite of economic importance; one in the province of Ontario, in which the above observations were made by the writer previous to 1866, including parts of the counties of Lanark, Leeds, and Frontenac; and the other, since made known, in the province of Quebec, chiefly in Ottawa county. In both cases it is found in the rocks of the Laurentian series, consisting of granitoid gneisses with bands of quartzite, of pyroxenite, and of crystalline limestone. These ancient and highly inclined strata, with a northeast strike, rise from beneath the horizontal paleozoic rocks near Kingston, and again pass beneath them near Perth. These overlying strata, belonging to the Ottawa basin, hide, moreover, to the eastward, the apatite-bearing gneisses of this district; which, a short distance to the westward, are again concealed by the Taconian and other overlying pre-Cambrian groups in Hastings county. The gneissic belt is here seen chiefly in the townships of Loughborough, Storrington, Bedford, North and South Crosby, and in North Burgess, where the apatite was first discovered.

The country presents a succession of small, isolated, rounded, rocky hills, alternating with numerous small lake-basins, hollowed

* Loc. cit., pp. 204, 224, 229.

out of the gneiss, and sometimes out of the interstratified limestones; the general trend both of the hills and the lakes being coincident with the strike of the rocks. These, though concealed in the valleys by considerable depths of alluvial soil, are seen in the hills to be hard and undecayed. These geographical features, as I have elsewhere pointed out, were apparently determined by sub-aërial decay previous to the erosion which removed from them the softened and disintegrated portions, leaving the present outlines.*

When, after cutting the forest-growth which covers these hills of granitoid gneiss, fire is allowed to pass over the surface, destroying the undergrowth, the comparatively thin layer of soil is laid bare, and is soon washed away by the rains; leaving the bald, rocky strata exposed in a manner singularly favorable for geological study, but rendering the region sterile. To prevent this process of denudation it has become the practice in some parts of the country, after burning over the hillsides, to sow them, without loss of time, with grass-seed, which, at once taking root, protects the soil from the destructive action of rains, and transforms it into good pasture-land. This system, which has been adopted to a considerable extent in parts of Frontenac county, Ontario, is worthy of record and of imitation in other regions.

The similar apatite-bearing gneisses, which are found to the north of the river Ottawa, a little northeast of the city of that name, are in Ottawa county, Quebec, and chiefly in the townships of Buckingham, Templeton, and Portland. They reproduce all the characteristics of the first-mentioned district, and may be looked upon as a prolongation of it beneath the northwestern limb of the paleozoic basin already mentioned. Later observations, both in Ontario and in this latter district, where mining operations have been carried on within the past few years, have been recorded by Messrs. Broome and Vennor, and by Dr. Harrington,—the latter up to 1878. They have, however, added little to our knowledge of the conditions of occurrence of the mineral beyond what had already been set forth in 1863 and 1866.

I have, within the past few months, examined with some detail many of the apatite-workings in Ontario, which have served to confirm the early observations, and to give additional importance to the fact, already insisted upon in previous descriptions, that the deposits of apatite are in part bedded or interstratified in the pyroxenic rock

* See the author's paper on "Rock Decay Geologically Considered."—*Amer. Jour. Sciences*, Sept., 1883.

of the region, and in part are true veins of posterior origin. The gneissic rocks, with their interstratified quartzose and pyroxenic layers, and an included band of crystalline limestone, have a general northeast and southwest strike, and are much folded; exhibiting pretty symmetrical anticlinals and synclinals, in which the strata are seen to dip at various angles, sometimes as low as 25° or 30°, but more often approaching the vertical. The bedded deposits of apatite, which are found running and dipping with these, I am disposed to look upon as true beds, deposited at the same time with the inclosing rocks. The veins, on the contrary, cut across all these strata, and, in some noticeable instances, include broken angular masses of the inclosing rocks. They are, for the most part, nearly at right angles to the strike of the strata, and generally vertical, though to both of these conditions there are exceptions. One vein, which had yielded many hundred tons of apatite, I found to intersect, in a nearly horizontal attitude, vertical strata of gneiss; and in rare cases what appear, from their structure and composition, to be veins, are found coinciding in dip and in strike with the inclosing strata.

The distinction between the beds and the veins of apatite is one of considerable practical importance,—first, as related to the quality of the mineral contained, and second, as to the continuity of the deposits. The apatite of the interbedded deposits is generally compactly crystalline, and free from admixtures, although in some cases including pyrites, and more rarely magnetic iron-ore, with which it may form interstratified layers. Many will recall in this connection the bands of magnetite, with an admixture of granular apatite, found interstratified in parts of the great magnetic ore-deposit known as the Port Henry mine, near Lake Champlain, in Essex county, New York; where, in certain layers formerly mined, the apatite made up about one-half the bulk. I have seen an example of a similar association of magnetite and apatite from Frontenac county, Ontario. The latter mineral is, however, for the most part found included in the beds of pyroxene rock, already mentioned, which is generally pale green or grayish green in color, sometimes containing quartz and orthoclase, and distinctly gneissoid in structure.

The veins present more complex conditions; while they are often filled throughout their width by apatite as pure and as massive as that found in the beds, it happens not unfrequently that portions of such veins consist of coarsely crystalline, sparry calcite, generally reddish in tint, holding more or less apatite in large or small crystals, generally with rounded angles, and often accompanied by crys-

tals of mica, and sometimes of pyroxene and other minerals. Occasionally these mixtures, in which the carbonate of lime generally predominates, will occupy the whole breadth of the vein. These *lime-veins*, as they are called by the miners, sometimes include cavities from which the carbonate appears to have been dissolved by infiltrating waters, leaving free the inclosed crystals of apatite. In some cases, however, these veins present cavities which have apparently never been filled with solid matter, and exhibit drusy surfaces, with quartz, and more rarely with barytine and zeolites. These calcareous veins often carry so much carbonate of lime as to be valueless for commercial purposes, unless some cheap means for separating the apatite can be devised. It may be said, in general terms, that while some of these true veins, throughout portions or the whole of their breadth, yield good and pure apatite, others are of comparatively little value. The bedded masses, on the contrary, are free from carbonate of lime, and although they may occasionally contain small quantities of mica, pyroxene, hornblende, or pyrites, these are seldom present to an injurious extent.

The question of the continuity of these deposits of both classes is an important one. Veins filling fissures that have been formed in rocks are sometimes continuous for great lengths and to great depths, but experience shows that their extent varies very much for different regions and for different rocks. Inclined beds, which were once horizontal sheets, inclosed in strata that have since been folded, should be as persistent in depth as they are in length; and when traced in the outcrop for many hundreds of feet, may be expected, under ordinary circumstances, to continue downwards as far, unless a turn of the inclosing strata brings them up again to the surface. The inclosed beds of apatite in the regions already noticed are often traced for 500 to 1000 feet and more, and there is reason to believe that they are continuous for long distances. The workings upon them have, however, as yet been very superficial, generally from twenty to forty feet, and rarely exceeding 100 feet. The deepest mine, which is in Ottawa county, is now about 200 feet.

The ordinary thickness of the bedded masses of apatite may be said to vary from one to three and four feet, though not unfrequently expanding to eight and ten feet, and even more, and sometimes contracting to a few inches; the same layer being subject to considerable variations. In some cases the apatite in a bed is found to thicken and then to diminish, or to be divided by the interposition of the accompanying pyroxenic rock. The condition of the apatite in these

cases recalls the thickening and thinning sometimes observed in a layer of coal among disturbed strata, where, as the result of great pressure attending the movements of the harder inclosing rocks, it is alternately attenuated and swollen in volume; in which case a thinning in one part is necessarily compensated for by a thickening of the parts adjacent.

The thickness of the veins also, as above stated, is very variable, and the same vein in a distance of a few hundred feet will sometimes diminish from eight or ten feet to a few inches. We have already noticed the variable nature of the contents of these veins, which are sometimes filled with solid and pure apatite, and at other times present bands or layers of this mineral, with others chiefly of calcite, of pyroxene crystals, or of a magnesian mica, occasionally mined for commercial purposes. While these veins have yielded in many cases considerable amounts of apatite, they have not the persistency of the beds. Their study presents many interesting facts in paragenesis, which I have described in detail in the report of the geological survey for 1866, already quoted, and more briefly in my *Chemical and Geological Essays* (pp. 208–213).

It is worthy of remark, that some of the first attempts at mining apatite in Canada were upon these veins, and that their irregularities contributed not a little to the discouragement which followed the early trials. The larger part of the productive workings are upon the bedded deposits. These, however, as already noticed, are for the most part opened only by shallow pits; a condition of things which is explained by the peculiar character and the frequency of the deposits, and also by the economic value of the apatite. This mineral, unlike most ordinary ores, is, in its crude state, a merchantable article of considerable value, and finds a ready sale at all times, even in small lots of five or ten tons. Like wheat, it can be converted into ready money, at a price which generally gives a large return for the labor expended in its extraction. Hence it is that farmers and other persons, often with little or no knowledge of mining, have, in a great number of places throughout the district described, opened pits and trenches for the purpose of extracting apatite, and at first with very satisfactory results. So soon, however, as the openings are carried to depths at which the process becomes somewhat difficult from the want of appliances for hoisting the materials mined, or from the inflow of surface-waters, which in wet seasons fill the open cuts, the workings are abandoned for fresh outcrops, never far

off. In this way a lot of 100 acres will sometimes show five, ten or more pits, often on as many beds, from twelve to twenty feet deep; each of which may have yielded one or more hundred tons of apatite, and has been abandoned in turn, not from any failure in the supply, but because the mineral could be got with less trouble and cost at a new opening on the surface near by.

These conditions are scarcely changed when miners, without capital and unprovided with machinery for hoisting or for pumping, are engaged, as has often been the case, to extract the mineral at a fixed price per ton. These, having no interest in the future of the mine, will work where they can get the material with the least expenditure of time and labor, and often will quit the opening for some one which is more advantageous. The very abundance and the value of the mineral mined has thus led to its careless, wasteful, and unskilful exploitation. It is the working of these causes, in the way just explained, which has thrown undeserved discredit on this mining-industry, and, more even than the injudicious schemes of speculators and stock-jobbers, has retarded its legitimate growth.

It is evident that the proper development of these deposits will require regular and scientific mining in place of the crude plan of open pits and trenches, which, from causes already explained, has hitherto, with few exceptions, been followed. As a basis for calculation in mining, it becomes necessary to establish some data as to the production and the value of the apatite-layers which we have described. The specific gravity of the mineral, as deduced from many specimens of massive Canadian apatite, is from 3.14 to 3.24. If we assume 3.20, this will give for the weight of a cubic foot of apatite almost exactly 200 pounds. A fathom of ground, carrying a bed or vein of apatite one foot in thickness, will thus contain thirty-six cubic feet, or 7200 pounds of apatite; equal to a little over three and one-fifth tons of 2240 pounds each. Allowing the fractional portion, equal to nearly seven per cent., for loss in mining (it will be noted that coarse and finely-broken apatite are equally merchantable), we shall have as the net product of a layer of apatite for a fathom of ground mined, three gross tons for each foot in thickness.

The apatite of these deposits is generally greenish in color, often clear sea-green, but more rarely reddish-brown in tint. The massive varieties are sometimes coarsely crystalline and cleavable, but sometimes finely granular. The veins often yield crystals of large size.

The mineral is essentially a fluor-apatite, containing not over two

or three thousandths of chlorine, and in its purest state about 92.0 per cent. of tricalcic-phosphate. The analysis of a selected specimen gave me 91.2 per cent. of phosphate, but it is generally mingled with small portions of foreign matters, chiefly insoluble silicates. The analyses of seven specimens from different Canadian mines, published by Mr. C. G. Hoffman in 1878, showed from 85.2 to 89.8 per cent. of phosphate.

The market-value of apatite, which, as is well known, is chiefly consumed for the production of soluble phosphate by the manufacturers of artificial fertilizers, varies greatly, other things being equal, with its purity. Thus, while at present the price in England is 1*s.* 2*d.* the unit for apatite giving by analysis 75 per cent. of tricalcic phosphate, there is paid an addition of one-fifth of a penny for each unit of phosphate above that percentage, so that a sample yielding by analysis 80 per cent. is worth 1*s.* 3*d.* the unit. The price in the English market is subject to considerable fluctuations, having within the last four years been as high as 1*s.* 5½*d.*, and as low as 11*d.* the unit for 80 per cent. phosphate. The present may be considered as an average price.

The Canadian apatite shipped to England has yielded for various lots from 75 to 85 per cent., 80 per cent. being the average from the best-conducted mines, though lots from mines where care has been used in the dressing and selection of the mineral for shipment have yielded 84 and 85 per cent. Many of the smaller miners to which we have alluded, selling their product to local buyers, take little pains in dressing, and hence their product is apt to be lower in grade. It will be seen, from the rule adopted by foreign purchasers, that there is great profit in a careful selection and dressing of the mineral for market. The basis being 1*s.* 2*d.* the unit for 75 per cent., with a rise of one-fifth of a penny for each unit, it follows that while a ton of 75 per cent. apatite will bring only 87*s.* 6*d.*, a ton of 80 per cent. will command 100*s.*, and one of 85 per cent. 113*s.* 4*d.*

In the present state of the industry it is not easy to say what would be the cost of production. At the outcrop of the large masses of apatite, and in the open cuts and quarries already described, the cost of extraction and dressing is of course very variable, estimates in different deposits giving from $2 to $8 the ton. In Ottawa county, where, within the last four years, deposits have been opened and mined on a better system than heretofore, the figures of production and cost are instructive. According to the report of its

manager in July, 1882, the High-Rock mine, in Buckingham, yielded, in 1880, 2400 tons, and in 1881 2000 tons of apatite. An adjoining portion of land having been then acquired, the production of this company's mines in 1882 and 1883 is stated at 5000 tons annually; from eighty to ninety men being employed. The cost of the mineral is here given at $4 the ton, dressed, at the mine; in addition to which $3 is paid for carriage to the railroad or the river, and about $1 additional to Montreal, the port of shipment. The mines in the Ontario district are for the most part in or near to the waters of the Rideau Canal, or some of the many lakes connected therewith, from which the freight to Montreal is $1.50 the ton. I am informed by a merchant, who is a purchaser and shipper of apatite, and is also engaged in mining it both in Ontario and Quebec, that the average cost for freight from Montreal to England, with selling-charges, is 20s. the ton; which, for apatite of 80 per cent., now worth 100*s*. the ton, would leave 80*s*., or $19.36. Deducting from this the cost of production and of transportation to Montreal, there remains a large profit.

The amount of apatite shipped from Montreal has gradually increased, and, according to published figures, attained, in 1883, 17,840 tons, of which it is to be remarked that 1576 tons were delivered in Hamburg, and 650 in Stockholm, the remainder going to Liverpool, London, and other British ports. Of this about 15,000 tons were from Quebec, and the remainder from Ontario. It should be noticed that this was, with small exceptions, mined in 1882, and brought to the water-side during the winter season. It is estimated that the shipments of apatite for 1884 will equal 24,000 tons.

The methods of mining hitherto generally pursued in the apatite deposits of Canada, allow of many improvements which would materially reduce the average cost of production, and give a permanency to the industry which the present modes of working can never attain. The regularity and persistence of the bedded deposits, and of some of the veins, warrants the introduction of systematic mining by sinking, driving, and stoping, with the aid of proper machinery for drilling, as well as for hoisting and pumping. The careful dressing and selection of the apatite for the market is also an element of much importance in the exploitation of these deposits. The cost of labor in the apatite-producing districts is comparatively low, and there are great numbers of beds now superficially opened, upon which regular mining operations, conducted with skill and a judicious expenditure of capital, should prove remunerative. It must be added, that the

areas in question have as yet been very partially explored, and that much remains to be discovered within them, and also there is reason to believe in outlying districts; so that in the near future the mining of apatite in Canada will, it is believed, become a very important industry.

THE QUEMAHONING COAL-FIELD OF SOMERSET COUNTY, PENNSYLVANIA.

BY JAMES P. KIMBALL, LEHIGH UNIVERSITY, BETHLEHEM, PA.

INCIDENTAL to a description of the hydrographical basin of the Quemahoning in Somerset county, Pa., as a coal-field, I have, without a personal survey of the whole county, taken the pains to collate a synopsis of leading facts, so far as available, relating to its coal resources. This is here presented, in view of an interest in the subject, growing out of a nearly central traverse of the county, in common with the southern tier of counties of the State, west of Blue mountain, by a new trunk line of railway—the South Pennsylvania.

The political east-and-west boundaries of Somerset county, Pa., following the bold topography of Allegheny mountain and Laurel hill, are in common with the east-and-west boundaries of the First Bituminous Coal-basin formed by these ridges respectively, except the southeastern townships which lie on the eastern slope of Allegheny mountain. The nearly parallel anticlinals of Negro mountain and the so-called Viaduct axis stratigraphically divide the basin into three sub-basins, which, in order from east to west, are known as follows, viz.:

I. *Berlin-Salisbury* (*Eastern*) *Sub-basin:* Between Allegheny mountain and Negro mountain, embracing the Berlin section of Barren coal-measures, the Salisbury section of Upper Productive coal-measures, and the Meyersdale and Garrett sections of Lower Productive coal-measures.

II. *Somerset* (*Middle*) *Sub-basin:* Between Negro mountain and the Viaduct axis, so called from the viaduct on the Conemaugh river, which there crosses it; embracing the section of Lower Productive measures of Mineral Point and Casselman on Castleman river, and of Somerset.

III. *Johnstown-Confluence* (*Western*) *Sub-basin:* Between the Viaduct stratigraphical sub-axis (which is less strongly marked topograpically in Somerset county as a ridge than in Cambria county), and the Laurel Hill grand axis. The synclinal of this sub-basin is crossed by the Conemaugh near Johnstown, and by the Castleman

river near Confluence. Hence the name. This sub-basin embraces the section of Lower Productive measures at Listonville, south of the Castleman, and of Harnedsville on that river; of Laurel Hill creek, north of the Castleman, and of Quemahoning creek.*

The Berlin-Salisbury sub-basin expires just north of the Cambria county line by the merging of Negro mountain with Allegheny mountain.

The Somerset sub-basin is a southwestern prolongation of the so-called Wilmore sub-basin of Cambria county.

The Johnstown-Confluence sub-basin of Somerset county is a similar extension of the Johnstown basin of Cambria county.

The Viaduct sub-axis rises into a prominent ridge in Cambria county southwest of Ebensburg. The Conemaugh and Stony creek in crossing it cut it down to the base of the Mauch Chunk red shale (XI) to a depth of some 600 feet. The Quemahoning has scored it some 100 feet into the Pottsville conglomerate (XII) to a depth of some 300 feet. The Viaduct axis is spanned by the coal-measures, the section of which is thinner or thicker as it rises or declines on the uneven back of the conglomerate. Near Davidsville, where it is at its lowest level, it is spanned by as much as 100 feet of the Lower Barren measures. Thence it rises at the rate of about 35 feet to the mile ($\frac{1}{3}°$) southwestward to the Quemahoning gap, whence it declines toward the Castleman, again rising south of that river at the rate of about 130 feet to the mile. In Somerset county, therefore, the same as in Cambria county, where it declines in the opposite direction beyond Ebensburg, the Viaduct sub-axis scarcely makes itself apparent at the surface. It is indicated, however, strongly enough in its several water-gaps. Its topographical features are those commonly exhibited by elevated areas, overspread with a thick section of the coal-measures under gentle dips, namely, a fertile upland eroded by water-courses and streams. Such is the surface north of Castleman river in both the Somerset and Johnstown sub-basins of Somerset county. The local term, *glades*, is aptly applied to this portion of the county.†

The divide between the waters of the Conemaugh (Shade, Stony, and Quemahoning creeks) and those of the Castleman (Coxe's, Middle and Laurel Hill creeks) is an elevated plateau several miles in width crossing both the Somerset and Johnstown sub-basins. The location of the South Pennsylvania Railroad follows this central watershed.

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* See beside the two plates herewith a map of Somerset county, with reference list of sections and mines, Second Geological Survey of Pennsylvania, HHH, 1879.

† See Second Geol. Sur., Pa., Chapter VI., Report HHH, 105.

This plateau is overspread with the Lower Barren coal-measures. The springs and streams which flow from it have sculptured it into hill and dale, along the slopes of which limestones and thin coal-seams of this series of strata indicate their presence by terraces or benches. As the water-courses deepen and expand, lower coals and limestones are cut successively on the hillsides and in the bottoms, down to the base of the Lower Productive measures, including the Freeport and Kittanning groups of coals and limestones. Edges of these are found near the surface in the valleys of the above-mentioned lower waters of the Conemaugh and Castleman.

The central plateau rises to nearly the same general level as the Viaduct sub-axis as well as that of Negro mountain, where this lateral summit joins these longitudinal ridges. In the vicinity of this elevated belt, the dips of the coal-measures are the regular transverse N.W.–S.E. dips from these sub-axes, slightly modified by a few minor longitudinal flexures of the same major folds of the palæozoic strata. Whether thus departing from a regular dip or not, these dips are so low as to become sensible only within a considerable compass, except where further modified by local dips of the nature of rolls.

Like the Viaduct sub-axis, that of Negro mountain, dividing the eastern and middle sub-basins, is obscurely marked topographically north of the central watershed where it is spanned by sections of the Lower Productive coal-measures, through which at intervals, as in the latitude of Stoystown, the upper sandstone member of the conglomerate (XII.) makes its appearance at the summit. North of the Castleman, it is locally known as the Ridge, its lack of prominence being due to the general elevation of the surface—especially in the neighborhood of the central watershed. South of the latitude of Berlin where the Ridge becomes denuded of coal-measures, it assumes the rugged features of a mountain.

The following levels of points on the line of the South Pennsylvania Railroad will serve to denote the elevation of the central watershed:

Boit's Summit,	2380 feet.
Keller's " (now Fike),	2400 "
Poorhouse,	2345 "
Floor of Negro Mountain tunnel,	2435 "
Maust's Ravine,	2100 "
Geisel's "	2280 "
Ream's "	2200 "
Weller's Church,	2240 "

The coal-mining industry of Somerset county is at present confined to the few sections of the county provided with such notoriously limited facilities as are supplied by the Baltimore & Ohio Railroad. The principal development is that of the Pittsburgh seam (7 to 8 feet) in the Salisbury and Meyersdale coal-field on Castleman river. The area of this lowermost and most important member of the Upper Productive coal-measures, which in the deepest part of the eastern sub-basin of Somerset county has escaped erosion, is a narrow belt between Meyersdale and the Maryland line, computed by the State geological surveyors to be 3615 acres in actual area. The whole of this area, however, is not equally available. It steadily narrows and becomes broken into isolated patches as it approaches Mason & Dixon's line, which it does not cross.

The Berlin coal-field of the same sub-basin, next in the order of development, is chiefly occupied with the 4-feet Berlin coal seam of the Lower Barren coal-measures. They emerge from beneath the Upper Productive series of the Salisbury coal-field in the vicinity of Meyersdale, forming the northern margin of the depressed portion of the eastern sub-basin as far north as Berlin. Here the several coal-seams of this group of strata, five in number, assume, by way of exception to their general characters, workable proportions. Only two of them, however, namely, the Berlin (upper) and the Price beds, have thus far proved sufficiently free from slaty intercalations to afford marketable coal. This coal-field is about six miles long, and some three miles wide.

Since the survey of Somerset county by the present State Geological Survey, importance has been given to the Price coal-bed of the Barren measures by boiler tests of its product from the mines of the Standard Coal Company and the Philson Iron & Coal Company, as reported by the Quartermaster General of the United States Army (Fuel for the Army, Washington, 1882). In a list of 45, comprising a large variety of coals, reported in the order of evaporative efficiency, the first and second examples are from these two mines respectively. Both have been opened some 1200 yards apart since the close of the field-work of the survey of the county, the first-named on the farm of Mr. H. N. Coleman, and the second on that of Mr. S. Coleman.

The only analysis of this coal I find available is one by Mr. McCreath. The sample was from the face of Mr. S. Price's heading, a neighboring mine, which, according to the Messrs. Platt, exhibited in 1876 the following section (Report HHH, 28).

Bony coal,	0′ 2″	2′ 9″
Coal,	1′ 0″	
Slate, knife-edge,	——	
Coal,	1′ 2″	
Slate, thin, non-persistent,	——	
Coal,	0′ 5″	
Slate,		0′ 3″
Coal,		1′ 0″
		4′ 0″

This section is essentially the same as that of the Philson Iron & Coal Company, as given me by Mr. H. N. Coleman. According to the same authority, the top bony coal is absent in the two openings on his farm, including the Standard Coal Company's mine, thus resembling the section given by the Messrs. Platt for Mr. Musser's mine, as well as in respect to the absence of mentionable slates in the upper bench.

The analysis referred to is as follows:

Moisture,	.870	100
Fixed carbon,	68 944	
Volatile matter,	20 330	
Sulphur,	1.176	
Ash,	8.680	
Coke,	78 80	

The approximate percentage of ash, complemental to the percentage of combustible given in the Quartermaster-General's tables, is 11.01 in the Standard Company's coal, and 9 08 in the Philson Company's It is obvious that the determination of ash by the analytical method should result in still larger proportions of ash.

Incomplete as are the results reported, especially for want of accompanying analyses, the two instances cited, compared with other examples in the list, tend to confirm at least one general deduction from most comparative experiments of the kind, namely, that a high calorific power in coals is not incompatible with moderately large proportions of ash. This point is not without special importance in its bearing upon the coals of Somerset county. As exhibited at present by available analyses, to be found in the Appendix to this paper, these seem to be comparatively rich in ash, but otherwise to conform to the best American type of highly calorific coals. Their brittleness or friability is one of the pronounced features of the type.

The operations of the Pittsburgh & Baltimore Coal, Coke & Iron Company, north of Ursina in the western sub-basin on the Rose or Philson bed of the Lower Barren measures, proved discouraging, and have been abandoned.*

Mining operations at Garrett on the Castleman in the Berlin-Salisbury (eastern) sub-basin are confined to the development of the Freeport Lower and Kittanning Upper seams of the Lower Productive measures, which rise from underneath the Berlin and Salisbury section on the eastern slope of Negro mountain, thus forming the western margin of that coal-field considered as one deep basin.

* See a judicious chapter on Variability of Barren Measure Coals, Report HHH, 251.

In the Somerset and Johnstown (middle and western) sub-basins, coal is mined and shipped from several points on the left bank of the Castleman and from its northern branches. The seams developed are those of the Lower Productive measures, especially the Freeport and Kittanning groups, of which the Kittanning Upper seam (C′) is the more extensively mined.*

QUEMAHONING COAL-FIELD.

JOHNSTOWN (WESTERN) SUB-BASIN OF FIRST GRAND BITUMINOUS COAL-BASIN.

Quemahoning creek is the west fork of Stony creek which enters the Conemaugh at Johnstown. Rising in the central watershed in Somerset township, some 4 miles N. W. of the town, its general N. E. course within the Johnstown sub-basin is nearly parallel in Jenner township to the axis of this basin. Hence it crosses into the Somerset sub-basin by its deep gap through the Viaduct sub-axis. Its tributaries flowing on the east from that portion of the elevated Viaduct anticlinal which is spanned by Lower Barren measures, and from an upland on the north and west likewise overspread with the same measures, its hydrographical basin south of the latitude of Jenner's Cross-Roads on the Bedford and Pittsburgh turnpike, affords the conditions for a remarkable development of the Lower Barren measures. While this series of soft strata goes far to determine its superficial topography and agricultural features, it is a lower series of coal-measures that gives importance to this area, namely—the Lower Productive series. The erosion of the hydrographical basin of the Quemahoning has scored a deep section of coal-measures down to the Kittanning Lower bed B so as to present this bed, together with the Freeport group of coals above water-level, under uncommonly favorable circumstances of dip and cover, and of accessibility for mining.

Along that portion of the boundary between Somerset and Cambria counties which is formed by Stony creek, the Kittanning and Freeport groups of coals are raised by the Viaduct anticlinal. Their several members are exposed above water-level in the sides of this deeply-eroded valley and in the hills of the adjacent country.

In the long narrow water gap of Stony creek through the Viaduct anticlinal, some 300 feet below the hill-tops, the Pottsville

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* I have adopted in this paper the nomenclature and notation of the later volumes of the Second Geological Survey of Pennsylvania. In the Appendix will be found its present full scheme of the Lower Productive coal-measures.

conglomerate (XII) is well above that stream. At the western end of the gorge, and on the Somerset county side of Red Bridge in the Johnstown sub-basin, the Kittanning Upper coal, C′(5 feet), is 145 feet above the creek.* Opposite the eastern end of the gorge in the Johnstown basin, the same seam ($4\frac{1}{2}$ feet net) is opened on the Somerset side on several farms and is exposed in the famous Hog's Back where its thickness is full 5 feet. Near Davidsville, some 3 miles southwest from the gap along the anticlinal, some 300 feet of the Lower Barren measures sweep across the anticlinal. It is here, according to the Messrs. Platt,† that the Viaduct axis is at its lowest elevation; that is, where the conglomerate floor of the coal measures is the deepest, and where therefore their fullest section in the anticlinal is preserved.

Southwest of Davidsville the Viaduct axis begins to rise again along its course. In the deep gap of the Quemahoning, some 100 feet of the conglomerate (XII) is exposed, and on the hill-tops the Kittanning Upper coal, some 300 feet above the stream. The State geological surveyors estimate the southwesterly rise of the Viaduct axis between the Quemahoning gap and its latitude of Davidsville to be about 30 feet to the mile, or about $\frac{1}{3}$ of a degree.‡ This anticlinal soon declines again along its trend southwest of the Quemahoning gap, and becomes merged in the upland of the central water-shed, and, buried beneath a varying section of soft lower measures, ceases to be a distinct topographical feature until recognized in the gap of the Castleman.§

The features of the hydrographical basin of the Quemahoning, within the limits of the Johnstown or western division of the First great basin of the Allegheny system, are simply topographical in character. They entirely lack those of a subordinate stratigraphical basin, like that of Salisbury in the eastern division of the First great basin. Nothing could be more simple than its structure. The coal measures have throughout a general dip of about N. 40° W., from 70 to 125 feet per mile. The maximum dip prevails along the upper part of the basin under its nearer approach to the Viaduct anticlinal. Declining about the centre to a minimum, it again increases toward the north, and reaches its maximum as it approaches the Viaduct axis to cross it. The general dip in relation to the fall of the creek is shown by the accompanying sketch map,

* Report H_3, 213.
† Ibid., 107.
‡ Ibid., 108.
§ Ibid., 109.

as well as the general topography, which is indicated by the stratigraphy of the several coal beds of the Lower Productive series here approximately exhibited without fine instrumentation.

Kittanning Lower Coal (B).

This coal seam is well known in Clearfield and Centre counties as the lower of the two beds which give repute to the superior steam coals of that region. In Blair county, at Bennington and vicinity, it is extensively mined for coking; in Cambria county, at Johnstown, Ben's creek and Lloydsville, chiefly for the same purpose. In the appendix to this paper an exhibit is given of analyses of coals from this seam as represented by the localities named. Upon an important point of identity see a foot-note in the appendix.

In Cambria and Blair counties its upper bench of 5 to 9 inches of bony coal, developed in most of the mines, is either left on the roof or else ripped after the extraction of coal to prevent casualties. In the vicinity of Bennington this seam is presented as a double one, with the same bony coal on the roof, and a middle parting of 12 to 15 inches. The upper bench only is mined, and free of its top bony coal. The lower bench of 27 to 36 inches is condemned for excess of sulphur and ash. In some of the mines at Bennington the bottom bench is of better quality, but often too much pinched by the thickening of the dividing slate for profitable mining. The upper bench of 2½ feet is mined free of its bony top of 6 inches. At Lloydsville the seam is separated into three benches, of which the two upper, aggregating some 5 feet in thickness, are mined free of the bony coal upon the roof. At Johnstown both top and bottom benches are rejected.*

The following is a list of sections of the Kittanning Lower coal (B) in Somerset county as compiled from Report H_3 of the present State Geological Survey of Pennsylvania:

Sections of Kittanning Lower Coal (B), North of Central Watershed in Somerset County, Identified by Second Geological Survey of Pennsylvania. Report HHH.

Somerset Sub-basin (Middle).

Lohr's Mine, Stony Creek, Hooversville. Coal 5 feet. Two thin slaty partings. (123)

Specht's Mine, Stony Creek, Sprucetown. Seam 6½ feet. Upper workable bench 2½ feet. Columnar and friable. Middle bench sulphurous 17 inches. Lower bench uneven and impure. Upper parting 3 inches, lower 6 inches. (126)

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* See paper by the present writer, read at the Troy Meeting: Differential Sampling of Bituminous Coal Seams, these *Transactions*, xii., 317.

Berkey's Mine, Shade Creek. Seam 6 feet. Upper bench 4 feet. Friable, clean coal. (142)
Custer's Mine, Shade Creek. Upper workable bench 50 inches (143)
Knebel's Mine, Shade Creek. Upper workable bench 49 inches. (144)
Morgan's Mine, Quemahoning. Seam 51 inches. Upper workable bench 3 feet. "Remarkably free from all impurities." (151)
Bowman's Mine, Viaduct anticlinal, branch of Quemahoning Creek. Seam 47 inches. Upper workable bench 3 feet. Good coal. (151)

Johnstown Sub-basin (Western).

No outcrops or openings above water-level positively identified by State Geological Survey. See text below for outcrops above water-level in the Quemahoning coal-field.

Berlin-Salisbury Sub-basin (Eastern).

Kuntz's Mine (?), Beaver Dam Run. Upper bench 8″, lower bench 34″ Parting ¼″. "Good, strong steam coal." Friable. (12)
McGregor's Mine, Dark Shade Creek. Upper bench 42″ alone mined. (13)
Grove's Mine, Clear Run. Upper bony coal 2″. Upper bench good coal 3′. Lower rejected bench 1 foot, with two slaty partings. (16)
Stadtler's Mine, summit of Allegheny Mountain. Gross 4′ 8″. Upper bench 3 feet. Good coal, which is shipped to Bedford County. (16)

SECTIONS OF KITTANNING LOWER COAL (B) IDENTIFIED BY SECOND GEOLOGICAL SURVEY, PENNSYLVANIA, IN SOMERSET COUNTY, BETWEEN CENTRAL WATERSHED AND CASTLEMAN RIVER. REPORT HHH, 1877.

Somerset Sub-basin (Middle).

Zimmerman's Mine, Kimberlin's Run (Coxe's Creek). Seam 4 feet. Upper workable bench 32 inches. (154) See Analysis.
Ankeny Mine, Milford Station, Coxe's Creek. Upper bench 26 inches. Parting ½ inch. Lower bench 8 inches. (165)
Brandt Mine, Milford, Coxe's Creek. Upper bench 33 inches. Parting 3 inches. Lower bench 7 inches. Thickness irregular. (166)
Baker's Mine, Coxe's Creek. 3 to 4 feet of coal. Same section as in Ankeny and Brandt mines.
Wolfersberger Mine, Castleman River, Mineral Point. Double bed. Upper bench 2½ feet. Parting 1 foot. Lower bench 1 foot.
Liston Mine, Listonville, Castleman River. 4 feet 2 inches. "Coal bright, tender, and seamed with slate and pyrites." (270) See Analysis.

Johnstown Sub-basin.

King's Farm, Laurel Hill Creek, Forwardstown. Not opened (1876). (243)
Harnedsville, Castleman River. Below water-level 3 feet. Good coal. (266)

BED B IN SOMERSET AND JENNER TOWNSHIPS, QUEMAHONING CREEK.

This bed underlies the whole of the Quemahoning (hydrographical) basin within the Johnstown or western synclinal. Maintaining its position very nearly at water-level, it is cut by the creek itself, and by several of its branches wherever it is sufficiently raised by local rolls,

as shown in the accompanying stratigraphical sketch. It thus appears on the Henry Shaefer farm in a ravine running into the creek, at a right angle, from the upland of the Viaduct sub-axis which forms the eastern margin of the section here described. In this ravine at the base of the hill to the north, it was opened several years ago alongside the road, in three places within a distance of 70 feet, but only for a few feet from its outcropping edge. The section here exhibited is as follows:

Shaly sandstone,	——
Black shale,	7′ 0″
Lustrous columnar coal,	0′13″
Shaly and bony parting	0′ 3″
Dull friable coal,	0 15
Bottom bench, not exposed,	
Gross thickness,	31″+

On the A. Hoffman place, back of Bulah church, it has been opened for a short distance under but little cover, by a rude opening, now several years old. This point is some 45 feet higher than at Shaefer's, and over 165 feet above the nearest point of the Quemahoning. The following is its section:

Shaly sandstone,	33′
Slate,	1′
Coal columnar,	0 18″
Fibrous coal,	1″
Coal columnar,	12″
Coal lamellar,	6″

Analyses of coal B at Hoffman's.

	I.	II.
Moisture,	1.892	1 88
Fixed carbon,	65.897	72.90
Volatile matter,	18.513	16.41
Sulphur,	3.078	0.98
Ash,	10.620	8.81

I.—Average of whole section of seam, exclusive of slate-parting (1″). Heading. Analysis by McCreath.

II.—Average of section exclusive of slate-parting (1″) and bottom bench (6″), from latest work 12 feet under cover. Analysis by Drown.

At Rischeberger's an old working still displays a section as follows:

Black shale roof,	
Coal in two workable benches,	2′ 3″
Parting,	¼″
Coal,	3″
Parting,	½″
Coal,	5″
	2′11¾″

Similar sections of coal B are presented in coal banks at Ogline's and Kiernan's. Shifting positions of its partings cause variations, however, in the relative thickness of its several members wherever observed—even within the narrow compass of a single coal bank.

A little beyond the northern limit of the section under description, the same seam has been wrought on a small scale at Bowman's, 1½ miles east of Jenner's on the Stoystown and Bedford turnpike. The Messrs. Platt give the following section for this opening (1876).*

Black slate,	
Coal good, workable bench,	3′ 0″
Slate,	0 1″
Coal,	0′ 5″
Slate,	0 ½″
Coal,	0 5″
Slate,	
Gross thickness,	3′11½″

Two miles north of the Cross-Roads, coal B may be seen at Apple's and Friedline's banks, when not "fallen shut." These, as well as Bowman's, were inaccessible at the time of my visit (October, 1883).

The State Geological Survey† gives the section of Morgan's bank on the same seam at the gap of the Quemahoning, as follows:

Black slate,	
Coal, workable bench,	3′ 0 ″
Slate,	0′ ⅛ ″
Coal,	0′ 3½″
Slate,	0 1 ″
Coal,	10 ″
Gross thickness,	4′ 2⅝″

In the latitude of Jenner's, on Shade creek, in the middle basin of Somerset county, the Kittanning Lower coal is reported at Berkey's and Custer's to present a gross thickness of some 5 feet, its upper benches yielding 4 feet of coal, described as excellent.‡ At Spruce-

* Report H_3, 152.

† Ibid, 151.

‡ Ibid., 142–143.

town, on Stony creek, some three miles to the south, in the same basin, this bed assumes an abnormal thickness ($6\frac{1}{2}$ feet), with two partings. The upper one, which is of fire-clay, is described as varying from a few inches to eighteen in thickness. The upper bench affords, according to the Messrs. Platt, $2\frac{1}{2}$ feet of tolerably pure coal.*

The above localities are all north of the central watershed. For these no analyses are given by the report of the State Geological Survey for the county (1877). Only two of bed B are given for the rest of the county, namely, at Fairview, on Negro mountain east of the town of Somerset, and at Listonville, south of the Castleman. The coal, at these two points, is seen to be condemned by the analyses furnished.†

The description of the Kittanning Lower coal above presented tends to show that it is at its best north of the central watershed, and in that part of Somerset county, to share, in some measure, the favorable conditions under which it is mined in the counties to the north, in the same great basin.

Kittanning Upper Coal (C′.)

In Cambria and the northern part of Somerset counties, this seam is wrought at several points on scales of greater or less magnitude, depending on the presence or absence of railway facilities. In Cambria and Blair counties, it is developed on an industrial scale for coking, and in Clearfield for steam purposes. North of the central divide of the county, in that section of Somerset which is still undeveloped by local industries, or by shipping facilities, its development is limited to the demand for local consumption, and for the calcining of the underlying Johnstown cement bed (limestone), which is mined in connection with it for agricultural use. In both sub-basins divided by the Viaduct anticlinal, it is invariably exhibited north of the central watershed of Somerset county, as a single bed 3 to 5 feet thick, free from persistent slaty partings, except such as at some points are found near the roof and bottom, and which, therefore, oppose no serious obstacle to mining.‡ While often in such seams ripped from entries for the sake of space in systematic workings, these are generally left unbroken in the rooms. The same practice is followed throughout the State in many of the best mines, in this and other beds of the same series.

South of the central watershed, a fire-clay shale regularly makes

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* Report H_3, 126. † Ibid., 154, 270.

‡ See this volume, p. 317 *et seq.*, On Differential Sampling of Bituminous Coal Seams, by the writer.

its appearance near the middle of the bed, gradually increasing in thickness towards the south to one to two feet on the Castleman, and to some five feet further south. Where thus occurring as a double bed, more than one of its benches is seldom mined. Thickening of the parting-shale is, as a rule, at a corresponding loss in size of the lower bench, which, as far as reported, is blocky and lamellar, and generally slaty. The upper bench is columnar, unevenly divided by a thin but persistent binder of slate, as on Middle creek.* Near the Maryland line both benches of coal aggregate but 27 inches.†

According to the Messrs. Platt,‡ the dividing slate of the Kittanning Upper (C′), first makes its appearance in Somerset county, near Hooversville in the Somerset sub-basin, as a thin, though persistent band, which expands in thickness toward the south, "swelling out to a foot along the Castleman, and becoming a regular and recognizable feature of the bed." Yet it does not, according to the same writers, make its appearance at Stoystown, in the same sub-basin some five miles still further south,§ nor does any such change take place in the Johnstown basin south of the latitude of Stoystown, on the Quemahoning.

Throughout the southern part of Cambria, and the northern townships of Somerset county, coal C′ "is invariably in one solid bench" stated to be about 2½ to 3 feet thick.‖ Within the area referred to, this seam seldom, if ever, presents less than a gross thickness of 5 feet, or less than 3½ feet of workable coal exclusive of top and bottom rejected benches. This is the case at the Rolling Mill mine, of the Cambria Iron Co., at Johnstown, where, as I am informed by Mr. John Fulton, 1½ feet of bony coal is left in the roof, except in roadways. At the Somerset county line, on Stony creek, near Red Bridge, the Kittanning Upper seam presents a breast of five feet of good coal,¶ described by the Messrs. Platt as blocky. At Scalp Level, on Paint creek, some five miles to the southeast, it maintains a net thickness of four feet, and is described as unusually free from all impurities.**

Like the Freeport seams in the two counties to the north, throughout the first great basin, the Kittanning Upper seam generally possesses a columnar cleavage. This structure, especially where not checked by intercalations of tenacious material in the form of minute binders of bony coal or slate, disposes the coal to crumble. I have

* Report HHH, 173.
† Ibid., 185–278.
‡ Ibid., 116, 119.
§ Ibid, 116.
‖ Ibid., 273, 313.
¶ Report HH, 127.
** Report HH, 62.

elsewhere explained, that coals the richest in disposable hydrogen, and poor in ash, are generally the more friable compared with dry coals verging upon the character of splint. This is illustrated by the well-known friability of the famous highly bituminous steam coals of the Moshannon basin of Clearfield county, and by the Berlin and Price coals of Somerset county.*

"The seam D (= C′) is divided, at Garrett, into two benches, by a persistent band of fire-clay slate which, in the Somerset and Johnstown-Confluence sub-basins to the west becomes its most prominent and characteristic feature."† This remark refers to the latitude of Garrett, and not to the northern portion of these sub-basins in Somerset county.

The following list of sections of the Kittanning Upper Coal (C′) in Somerset county, is compiled from the observations of the *Second Geological Survey of Pennsylvania,* made during the summer of 1876, as recorded in Report H_3. For analyses from the same source, see Appendix to this memoir.

NORTH OF CENTRAL WATERSHED.

Somerset Sub-basin.

Meyers Mine, near mouth of Shade Creek. Solid coal 3 feet 9 inches. Coal hard, compact, and blocky. (116)

Trevorrow Mine, Stony Creek Solid coal, 3½ feet. Firm and compact, clean coal. Good for steam and rolling-mill. (117) See analysis.

Eash Mine, Stony Creek. Solid coal 3 feet 3 inches. (118)

Swank Mine, mouth Quemahoning. Coal 4 feet; upper bench 3 feet, lower bench 1 foot. Parting ½ inch, noticed for first time in Somerset County, going south, half a mile below Hooversville.

Lohr's Mine, Stony Creek. Upper bench 3 feet. Good hard coal. Slate near bottom. (124)

Specht Mine, Stony Creek, Sprucetown. Seam 6 feet 6 inches; upper bench 2½ feet; two partings, 3 and 6 inches; lower bench irregular and slaty. (126)

Wilt Mine, Stoystown Seam 3 feet 11 inches, ¾ inch slate parting, upper workable bench 2 feet 9 inches. (127) See analysis.

Kimmel Mine, Beaver Dam Creek. Upper workable bench 2 feet 10 inches. Slate parting ¾ inch. Lower bench 6 inches. (128)

Reitz Mine, Stony Creek, Wells Br. Net coal 2½ feet. Coal tender. See analysis. (131)

Weaver Mine, Paint Creek, opposite Scalp Level, Cambria County. Seam 7 feet 1 inch. Lower workable bench 3 feet 10 inches to 4 feet. (135) (HH, 62)

Josiah Custer Mine, Shade Creek. Solid bench of hard bright coal 3 feet 8 inches. (140)

Rodger Mine, Shade Creek. Coal 3½ feet, solid bench. (145)

Weaver Mine, Quemahoning Creek. Coal over 3 feet, in one solid bench, good quality. (151)

* See this volume, p. 317 *et seq.*, Differential Sampling of Bituminous Coal Seams, by the present writer.

† Report HHH, 51.

Johnstown Sub-basin (Western).

Yoder's Mine, Conemaugh township, Stony Creek. Coal solid 4½ feet. "Hard and tough" (214)

Mushler Mine, same section. Coal firm and good "from the start." (214)

Beam (now Lohr) Mine, Quemahoning Creek. Seam 4 feet 8 inches. Upper bench 4 feet. (230.) See analysis.

Pile Mine, Quemahoning Creek. Seam 4 feet 5 inches. Upper workable bench 4 feet. (232.) See analysis from lower slaty bench.

BETWEEN CENTRAL WATERSHED AND CASTLEMAN RIVER.

Somerset Sub-basin (Middle).

Baer's Mine, Negro Mt. Coal 2½ feet. (156)

Wall's Mine, Negro Mt. Same section. (156)

L. Shaefer's Mine, Negro Mt. Same section. (158)

Kimmel's Mine, Kimberlin Run, Fairview. Seam 5 feet 5 inches. Parting 11 inches, upper slaty coal 2 feet, lower workable bench 32 inches. (159)

Fox's Mine, Kimberlin Run, of Coxe's Creek. Seam 4 feet. Upper workable bench 39 inches. (159)

B. Shaefer's Mine, Kimberlin Run. Seam 4½ feet. Upper bench 30 to 36 inches. Clay parting 6 inches. (160)

Weimer's Mine, Somerset, Cox's Creek, 30 feet below water-level. Seam 5 feet. Roof-coal, bony, 3 inches. Upper bench 27 inches, slate parting 8 to 11 inches. Lower bench 18 inches. (162)

Baker's Station, Cox's Creek, Double. 5 feet gross, parting shales 1 foot. (169)

J. Meyers, Middle Creek, Double. Lower bench 4 feet, upper 2 feet. Parting 13 inches. (173)

Walker's, Middle Creek, Double. Parting 2 to 3 feet. (174)

Henry Sechler's, Negro Mt., near Casselman. 46 inches gross, 44 inches net. Quality poor. (197)

Zufall's, Castleman R. Upper bench 31 inches. Parting 24 inches. Lower bench 12 inches.

Heinbach's, Castleman R. Upper bench 27 inches. Parting 24 inches. Lower bench 15 inches. (201) See analysis.

Nicholson's, Castleman R. Upper bench 21 to 24 inches. Parting 30 inches. Lower bench 24 inches. (201) See analyses.

Berlin-Salisbury Sub-basin (Eastern).

Hay's Mine, Garrett. Upper bench 4½ feet. Parting 3½ inches. Lower bench 21 inches. (51)

Garrett Tract, same section. Upper bench, 4½ feet, worked. (52)

Walker's Mine (Enterprise Coal Company), Garrett. Upper bench 18 inches. Parting ¾ inch. Lower bench 27 to 30 inches. (52)

Wigle Mine, Garrett. Gross 6 feet. No longer mined. (53) See analysis.

Johnstown Sub-basin (Western).

King's Mine, Laurel Hill Creek, Forwardstown. Upper bench 3 feet. Fireclay parting 18 inches. Lower bench 2 feet. (242)

Faidley Mine, Middle Creek. Upper bench 32 inches. Parting 8 inches. Lower bench 19 inches. Upper bench divided by 2 inches of slate. All three benches yield blocky, lamellar coal, very firm and slaty. (245)

Croll Mine, Laurel Hill Creek. Upper bench 11 inches. Parting 3 inches. Lower bench 11 inches. (255) See analysis.

Leslie Mine, Castleman R., Upper Turkey Foot. Upper bench 3 feet. Parting 2 to 4 inches. Lower bench 8 to 10 inches. (262)

Augustine Mine, Upper Turkey Foot. Gross thickness 4 feet. Parting 2 to 6 inches. (264)

Hanna Mine, Harnedsville. Upper bench 3 feet. (267) See analysis.

McClintock Mine, Harnedsville. Upper bench 2 feet. Parting, bony coal and shale, 13 inches. Lower bench 1 foot. (268) See analyses.

Kittanning Upper Coal C′, in Somerset and Jenner Townships, Quemahoning Creek.

This seam on the Quemahoning is from 80 to 85 feet above bed B. It has been opened at a number of points in connection with its adjacent limestone beneath, from which is exclusively obtained the local supply of limestone for burning into lime for agricultural purposes. Both the stone and the fuel for its calcination are produced from the same openings.

At Pile's it is opened 40 feet above the creek, under good cover, by four headings, radiating N. and W. from a central quarry. The dip is scarcely appreciable. The following section is from the eastern heading, some 300 feet in.*

Section I.

Fissile shale,	not mined 5 inches,	0′ 1″	4′ 7″
Lamellar coal,		0′ 4″	
Columnar coal,	workable 3′ 7″	11″	
Cannel, or bony coal,		2″	
Lamellar coal,		2′ 6″	
Gray shale,	not mined 8 inches,	2″	
Coal—solid layer,		3″	
Gray shale,		1″	
Solid coal,		2″	
Fireclay shale,		— —	
Limestone, 9 feet.			

Section II.

Another section at Pile's, taken in the short heading to the south, and from near the outcrop, is as follows:

Shale,	——	
Columnar coal,	10½″	4 feet.
Cannel parting, not separated,	2 ″	
Columnar coal,	35½″	
Bony coal,	6 ″	
Fireclay floor,	——	
Gross thickness,	4½ feet.	

* A similar section was observed in Joseph Shaefer's bank some 300 feet in, under good cover, about 100 rods below Pile's.

ANALYSES.

	Section I.	Section II.
Moisture,	1.60	1.016
Fixed carbon,	74.85	68.630
Volatile matter,	14.25	17.004
Sulphur,	1.59	3.264
Ash,	9.30	10.086

I.—Middle workable bench. Analysis by Drown.
II.—Sectional average of whole seam, as mined from particular heading. Analysis by McCreath.

The disparity in fuel ratios in the above two analyses arises from the freedom from slate in the one sample and its presence in the other. It also suggests such weathering as might be expected to arise from the relative differences of position, sample I. being sound coal from under good cover, while II. was from within 12 feet of the outcropping edge. The parting of so-called cannel is a firm non-lustrous coal which burns to a white ash.

The seam is well exhibited 70 feet above water-level, at Lohr's and A. Hoffman's banks, which are close together, separated by a boundary.

SECTION AT LOHR'S.

Black shale,	— —	
Lamellar coal, with variable non-persistent yellow slate, ¼″,	1′ 4″	3′ 2″
Cannel coal,	1″	
Lamellar coal,	1′ 9″	
Slaty coal,	9″	

Another section from the same mine (formerly Beam's) is given by the Messrs. Platt as follows:

Black slate,		— —
Coal, workable bench,		4′ 0″
Slate,	rejected,	0′ 2″
Coal,	rejected,	0′ 6″
Slate and clay,	rejected,	0′ 6″
Limestone.		

ANALYSES.

	I.	II.
Moisture,	1.27	0.820
Fixed carbon,	77.77	74.881
Volatile matter,	14.33	17.235
Sulphur,	0.66	0.519
Ash,	6.63	6.545

I.—Average of upper workable bench from heading, 250 feet in. Analysis by Drown.

II.—Upper bench. Reported by State Survey. (Report H_3, 230.) Analysis by McCreath.

The large proportion of lamellar coal in Lohr's and Hoffman's mines imparts to it prismatic cleavage and extraordinary tenacity as compared with the general type of the Freeport group of coals throughout the First Great Basin.

Reference will be had to the sketch-map for topographical features.

UPPER FREEPORT OR LEMON COAL-BED. (E.)

This coal-bed is wrought on an industrial scale at several points in Blair and Cambria counties, and at present on a small scale in Somerset county. The following is a tabular exhibit of sections, within the area of its development thus described.

Sections of Upper Freeport Coal, E, Mainly Compiled from Reports HH and HHH, Second Geological Survey of Pennsylvania.

	Roof bony coal or slate	Coal.	Parting.	Coal.	Parting.	Coal.	Gross thickness.	Net thickness.
BLAIR COUNTY.								
I. Lemon's Mine	..	34	1	16	3	6	5'0"	4'2"
II. Kittanning Coal Co	6	33	¾	15	...	. ...	4'10"	4'0"
III. Dennison, Porter & Co	4	35	2	16½	.....	... ..	4'9½	.. ...
CAMBRIA COUNTY.								
IV. Christy's.	6½	36	1	15	?	......	4'11"	4'4"
V. Curry's, Lilly Station ...	6	36	1¼	6	......	... .	4'1¼	4'0"
VI. Dysart & Co, Lilly Station	7	36	2	15	. . ..	.. ...	5'2"	4'0"
VII. Coshun Mine, Cambria Co.	12	20	¼	20	2½	2	3'8¾"	......
SOMERSET COUNTY.								
VIII. Thomas's, Conemaugh	.....	34	3	37½	......	19	6'9½"	3'1½"
IX. Queer's, Sipesville . .	......	34	1½	3½	1	4	3'8"	3'3"
X. Griffith's, Quemahoning crk	2	34	½	5	½	4½	3'10½"	3'1"
XI. Sipe's, Quemahoning creek		36	1½	13	2	3	4'7½"	4'2"
XII. Lape's, Quemahoning creek	....	35	1	5	1	6	4'0"	3'0"
XIII. Covode's, Quemahoning crk	2	37	1	5	1	5	4'3"	3'1"

I.—Lemon's old mines. Portage R.R., Blair county (Roger's Survey of Pennsylvania, II., 652; Second Geological Survey Report, HH, 24.)

II.—Kittanning Coal Company (Juniata Coal Company, lessees), near Bennington, Blair county. For analysis see Appendix. (Report HH, 22).

III.—Dennison, Porter & Company's old mine, near Bennington. For analysis see Appendix. (Report HH, 23.)

IV.—Christy's Mine, one mile northwest of Gallitzin's, Cambria county. (Report HH, 67.) Since the date of this report, the Glen White Coal & Lumber Company has opened another mine on this bed near Gallitzin.

V., VI., and VII.—Currey's Mine, and Dysart & Company's Mine, Lilly Station, Cambria county. Wilmore Sub-basin (Somerset or Middle Sub-basin of Somerset county). Bed E, according to the Messrs. Platt, yields four feet of good strong steam coal, soft, friable, and of columnar structure, exclusive of top bony bench. (Report HH, 30.)

At Johnstown, Cambria county, according to the same authorities. Bed E, at the Cambria Company's coke-yard mine, presents two partings and yields four feet of good but soft coal. (Report HH, 108, 112.) At the Coshun Mine of the same company, according to Mr. John Fulton, its thickness is three and one-half feet of clear coal.

VII.—Thomas's Mine, South Fork of Ben's Creek, Somerset county, Conemaugh township. The seam here, though unusually thick, yields thirty-seven inches of good coal. (Report HHH, 218.)

VIII.—Queer's and Samuel Berkey's Mines, two and one-half miles west of Sipesville.

IX.—Griffith's Mine, near mouth of Beaver Run, an affluent of the North Branch of Quemahoning Creek. Fallen shut at time of writer's inspection. (Report HHH, 228.)

X.—Sipe's Mine, three-fourths of a mile north of Jenner's, on the Stanton Mill Road. Sections from face of heading in 200 feet, under fifteen feet of cover.

XI.—Lape's Mine, 1½ miles southwest of Jenner's, Quemahoning Creek. Opened on same line of outcrop, on adjoining Besecker and Ludy farms. At Ludy's the decline of the seam from Lape's is some thirty feet.

XII.—Dr. Covode's Mine, Jenner's Cross-Roads, Quemahoning Creek. At present inaccessible, as it was opened upon an adverse dip. The main bench, according to the Messrs. Platt, yields a bright, rich, lustrous coal, which "if mined alone would doubtless produce a much better fuel than is yielded by the average of the whole bed." (Report HHH, 226.)

The valley of the Quemahoning, in the vicinity of Jenner's, exposes a section of 250 to 300 feet of strata from the Clarion coal seam, in the bed of the stream, up to the Barren measures, a con-

siderable thickness of which, with a number of unexplored coal seams, crowns the higher hills.

Analyses of Upper Freeport Coal (E), Quemahoning Creek.

	I.	II.	III.
Moisture,	1.256	1.27	1.21
Fixed carbon,	69.175	77.77	75.82
Volatile matters,	17.364	14 33	15.85
Sulphur,	2.125	0.66	0.95
Ash,	10.080	6.63	7.12

I.—Lape's average of whole section of seam.
II.—Lape's average, exclusive of bottom, one foot. Net coal three feet.
III.—Sipe's average, exclusive of bottom, nine inches. Net coal three feet.

The following sections of the Upper Freeport Bed (E) compiled from Report HHH, of the Second Geological Survey of Pennsylvania, are here presented for further comparison.

North of Central Watershed.

Somerset Sub-basin (Middle)

Barnhardt Mine, Stoystown, Wells Creek. Seam 3′ 5″. Upper workable bench, 3′. (130)

Berlin-Salisbury Sub-basin (Eastern).

No sections reported as positively indentified.

Johnstown Sub-basin (Western).

See above table.

Between Central Watershed and Castleman River.

Somerset Sub-basin (Middle).

J. Schaefer's Mine, Kimberline Run. Soft coal, of good appearance. (160)
Hugus Mine, Somerset. 45 inches. Upper workable bench, 29 inches. Sample analyzed probably included bottom slaty bench. (163)
Schupstein Mine, Somerset. Same section. (164)

Berlin-Salisbury Basin (Eastern).

No section reported as positively identified.

Johnstown Sub-basin (Western).

Putnam Mine (?), Middle Creek Township, Laurel Hill Creek, 39″. Upper bench, 30″. (240)
Barron Mine, Middle Creek Township, Laurel Hill Creek, 4′. Middle bench, 40″. Coal of "superior quality." (240)
King's Mine, Laurel Hill Creek. Stated by owner to be 5 feet gross. (242)
Rush Mine, Pittsburgh & Baltimore Coal, Coke, & Iron Company, Laurel Hill Creek, 2½ feet. Inferior, slaty coal. (254) See analysis.
Railroad Cut coal, Ursina, Castleman River. 30″ gross. Small and slaty. (257)

In the above description I have refrained from encumbering these pages with unnecessary details of topography, as these are clearly enough exhibited for all present purposes in the accompanying sketch-map.

Nor have I made mention of subordinate members of sections referred to, such as the Freeport Lower coal (D), of the Lower Productive measures, and the several members of the Lower Barren measures, except in instances where known to be of economic importance. Within the area under special consideration, that of the water-basin of the Quemahoning, these several members of both continuous series of strata, are frequently recognized by their smuts, or by their terraces within a sectional development as high as the Elk Lick coal and limestone, just beneath the Morgantown sandstone. This is recognized by its fragments near the summits of some of the higher hills south of Jenner's. While these horizons are usually indicated by at least rudimentary seams of coal, there has come to my knowledge no positive evidence tending to attach any importance to these in the northern townships of Somerset county.

While the southern parts of the county approach the southern limits of basins individual to the separate seams of the Lower Productive coal measures, as shown by increased sedimentation within the compass of the seams of this series, the conditions for deposition of coal continuous with the accumulation of the strata of the Lower Barren measures were, on the other hand, exceptionally favorable.

The practical knowledge of the coal-measures of Somerset county is limited to their elevated positions, little attention having hitherto been given to anything below the level of superficial drainage.

The replication of the lower series of coals, however, in the axes and sub-axes, and the erosion of a generously-watered section of country by the drainage of so much upland as these ridges afford, combine to present outcropping edges of these coals under circumstances of dip and cover, and at a sufficient number of points to render them readily accessible throughout the county. That this is especially the case in the water-basin of the Quemahoning has already been explained. Here the whole series of strata is under a general dip of less than two degrees (174 feet per mile), while local undulations do not exceed three or four degrees (5 to 6 feet per 100).

The Kittanning Lower coal-bed (B) is available above drainage, on the east side of the Quemahoning, and from Kiernan's and Hoffman's branches.

The Upper Kittanning coal (C′) is available above drainage, on the

west side of the Quemahoning, as far down as Solomon Simpson's, where it declines to within some 15 feet above low-water of the creek, and on the east side from all cross ravines.

The Upper Freeport coal (E) is available on both sides of the Quemahoning, under topographical conditions, which leave little to be desired.

The Quemahoning valley seems to present a natural grade for a railway, whether regarded as lateral of a main line, like the South Pennsylvania, now building, or for the development of its future coal industry. The several branches of the Quemahoning are likewise practicable for coal roads. So far as can be judged by the eye, a route from the line of the South Penn. R.R. to Johnstown seems to be offered by the Quemahoning to a point below Jenner's, thence by apparently practicable grades across a divide to Ben's creek. This would give access to a good portion of the Johnstown sub-basin, in Cambria county, south of that city, as well as to one of the most thickly settled parts of Somerset county. Such a lateral would be in line with a southern branch to the town of Somerset.

My first examination of the Quemahoning coals was in company with Professor J. J. Stevenson, with whose coöperation their stratigraphy was sketched in the field.

For purposes of reference, I append Professor Lesley's compiled section of Lower Productive coal-measures, as typical in the First Basin,* extended by Mr. John Fulton's section;† and also a compiled section of the Upper Productive coal-measures in Somerset county, from the same volume (p. 287).

UPPER PRODUCTIVE COAL-MEASURES, 215 FEET.

	Feet.	Inches.
Sandstone,	40	0
Uniontown coal,	2	1½
Clay,	1	6
Uniontown limestone,	12	4
Interval,	45	
Coal,	1	
Interval,	8 to 10	
Sewickley coal,	2	
Sewickley limestone,	10	
Interval,	44	
Redstone coal,	3	2½
Interval,	3	11
Redstone limestone,	13	1
Interval,	10	
Coal, Rider of Pittsburgh,	3	
Slate,	4	
Pittsburgh coal,	10	
Interval,	54	

LOWER BARREN MEASURES, 550 TO 600 FEET.

	Feet.	Inches.
Little Pittsburgh coal,	2	
Little Pittsburgh limestone,	5	
Interval,	17	
Coal, small,	..	
Slaty standstone and iron ore,	13	
Coal, small,	..	
Interval,	38	

* Report H_3, 297.

† Ibid., p. 307.

	FEET	INCHES.
Coal,	1	
Slate,	8	
Interval: Equivalent of Morgantown sandstone,	62	
Elk Lick coal-bed,	2 to 4	9
Interval,	25	
Elk Lick limestone,	5 to 10	
Interval,	65 to 70	
Berlin coal-bed,	3	8
Interval,	10	
Berlin limestone,	8	
Slate and shale,	5	
Platt coal-bed and slate,	7	
Interval,	60	
Price coal-bed,	4	
Interval,	60	
Coleman coal-bed,	1	10
Slate,	...	6
Coleman limestone,	3	
Interval,	40	
Philson or Rose coal-bed,	1	6
Philson limestone,	3	
Interval: Place of Johnstown iron ore (near bottom),	40	
Gallitzin coal,	1	8
Mahoning sandstone,	60	

*LOWER PRODUCTIVE COAL-MEASURES, 300 + FEET.

	FEET.	INCHES.
Upper Freeport coal-bed, E,	4	
Upper Freeport limestone (frequently wanting),	...	
Interval,	60	
Middle Freeport coal-bed, D′,	2	6
Middle Freeport limestone (frequently wanting),	...	
Interval,	60	
Lower Freeport coal, D, averaging,	3	
Lower Freeport limestone. Johnstown cement-bed. Almost universally present in Somerset and southern part of Cambria county, but wanting in northern part of Cambria and in Clearfield and Centre counties,	...	
Interval,	50	
Kittanning coal-bed, C, averaging,	1	6
Interval,	30	
Coal-bed, B′, averaging,	1	
Interval,	20	
Clarion coal-bed, B,	4	
Interval,	24	
Coal-bed, A′, averaging,	1	
Interval,	20	
Brookville coal-bed, A, averaging,	4	
Piedmont sandstone,	50 to 75	
Mt. Savage coal-bed,	2	
Pottsville conglomerate,	100 +	

* LOWER PRODUCTIVE COAL-MEASURES.

(*New System, Reports H_5, V_2.*)

Mahoning sandstone.
Freeport upper coal (E).
Freeport upper limestone.
Freeport lower coal (D).
Freeport lower limestone.
Kittanning upper coal (C′).
Johnstown cement-bed.
Kittanning middle coal (C).
Coal-bed (B′).
Kittanning lower coal (B).
Ferriferous limestone.
Clarion upper coal.
Clarion lower coal (A′).
Clarion sandstone.
Brookville coal (A).

Analyses of Kittanning Lower Coal-bed (B), Compiled chiefly from Report HH (1877).

NAME OF MINE.	Thickness. Gross.	Thickness. Net.	Water at 225°.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Coke.	
Blair County.									
Glen White Coal & Lumber Co....... ..	5'5"	2'7"	0.940	29 660	59 912	0 978	8 510	69 40	McCreath, HH, 12, Upper bench, 2'7".
Glen White Coal & L. Co., Bennington			1.040	28.010	49 244	4 501	17 205	70.95	McCreath, HH, 2, Lower bench, 2'6".
Woodvale, Bennington, Cambria I. Co.	.....	2'6"	.....	22.38	68 50	1 12	8 00	76.00	T T. Morrell, Pa. Ind. Sta., 235.
Bennington Shaft, Blair I & C Co. a section of Cambria Iron & Coal Co.	4'	2'7"	1.400	27 225	61.843	2 602	6 930	71 375	McCreath, HH, p. 16.
Dennison, Porter & Co..........................	3'8"	2'6"	0.910	26.340	64.373	1.792	6 585	72.75	McCreath, HH, p 18.
Cambria County.									
Cambria Iron Co	3'8"	3'6"	.. ..	20 33	70.83	2 73	8.83	79.67	T. T. Morrell, HH, 105. MM, 72.
Johnstown Manufacturing Co . . .	.	.. ..	1 185	16 540	74 456	1.86	5 959	82 275	McCreath, HH, 105, MM, 72
South Fork, Cambria Coke & Coal Co...	5'9"	4'3"	1.100	17.240	73.145	2.352	6.163	81 660	McCreath, HH, 44, Upper bench.
Dysart & Co., Ben's Creek.	5'10"	3'11"	0.615	17 935	76.503	0 602	4 345	81.45	McCreath, HH, 49.
Lloydsville, Bell's Gap R. R. Co.........	av'ge	...	0 630	24.230	59 216	2.239	13 685	75.14	McCreath, HH, 86, Upper bench, 2½'.
			0 710	26 065	64 806	1 509	6 910	73.225	McCreath, HH, 87, Middle bench, 2½.
	6' to 7'	5'	0.970	26.130	63 624	2 581	6 695	72 90	McCreath, HH, 87, Lower bench, 1'8".
Centre County.									
Moshannon Creek.									
Powelton, Powelton Coal & Iron Co ...	6'	4'8"	0 540	22 560	71 551	1 079	4 270	76 90	McCreath, Lower bench, 1'2".
Powelton, Lower Bench (1'2")	......	. . ..	0.600	22 600	68.709	2.691	5 400	76.80	McCreath, Upper bench, 3'8", H, 39.

Analyses of Kittanning Upper Coal-bed (C′), Clearfield Steam Coal region, Compiled from Report H (1875).

NAME OF MINE.	Thickness. Gross.	Thickness. Net.	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Coke.	
CLEARFIELD COUNTY.									
Moshannon Creek.									
Hale's	3′8″ to	3′10″	0.740	25.210	68.628	2.122	3 300	74 050	Page 42.
New Moshannon. Moshannon L. & M. Co.	6′2″	5′8″	1.100	23 070	71.199	0 611	4 020	75 830	Page 37.
Mapleton P. S. McCalmont	4′5½	3′11″	0 700	23.565	68 890	1.715	5 130	75.735	Page 43, exclusive of top bench.
Laurel Run, Nuttall, Bacon & Co.	4′4″	3′11″	0.800	23 260	72 350	0 590	3 000	75.940	Page 45, exclusive of top bench.
Derby, Lower, Thomas Barnes & Bro.	4′8″	3′4″	0 41	22.81	66.69	1 79	8 30	76 78	Page 47
Decatur, Decatur Coal Co.	4′6″	4′	0.640	24.360	64 082	3.378	7 540	75.00	Page 48, lower bench, 1′2″.
Decatur, Decatur Coal Co	...	......	0.820	23.900	69 007	1 373	4 900	75 28	Page 48, main upper bench, 2′10″.
Decatur, Coke from slack	...	......	......	...	...	0.867	6 300	...	Page 49, run of mine
Morrisdale Branch R. R.									
Morrisdale, R. B. Wigton & Son	4′3″	4′	0 55	24 09	71 689	0 571	3.10	75 36	Page 49, lower bench, 1′1½″.
Morrisdale	...	.....	0.56	25.19	71.013	0.587	2.65	74 25	Page 50, main upper bench, 3′.
Morrisdale, Coke from slack	..	....	...	....	..	0 643	7.670	...	Page 51, run of mine

Johnstown Sub-basin of First Bituminous Coal-basin, Compiled from Report HH.

NAME OF MINE.	Thickness. Gross.	Thickness. Net.	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Coke.	
CAMBRIA COUNTY.									
Johnstown, Cambria Iron Co.	5′	3′6″	... ..	16 58	76 87	0.472	6.55	83 42	Page 109 {by T. T Morrell, sulphur stated
Johnstown, Rolling Mill Mine.	....	3′6″	1.140	17.180	73.421	1.408	6 848	81 680	Page 110 {to be below average.

Analyses of Moshannon or Freeport Lower Coal-bed (D): Clearfield Steam Coal-region. Compiled from Second Geological Survey of Pennsylvania. Report H (1874).

NAME OF MINE.	Thickness. Gross.	Thickness. Net	Water at 225°.	Volatile matter.	Fixed carbon.	Sulphur	Ash.	Coke.	
CLEARFIELD COUNTY.									
*Houtzdale.**									
Penn, Reakert Bros. & Co......	.....	42″58″	0 810	20 640	74 023	0.507	4.020	78.550	McCreath, H 29.
Franklin, Kittanning Coal Co	.. ..	58″64″	0 670	21 360	74 284	0 435	3 251	77.91	McCreath, H 30.
Franklin, Kittanning Coal Co..........	.. .	.....	.. .	20 100	76 39	0.19	3 510	79 09	Seeley Furnished by company.
Eureka, Berwind, White & Co. .. .	5′6″	4′6″5′	0 78	21.680	73 052	0 688	3 800	77 540	
Eureka, No. 2, Berwind, White & Co.	5′9″	4′3″	1 15	19 50	77 05	.. .	2 30		Booth, Garrett & Blair. Furn'ed by operators H31
Webster, Webster Coal Co	5′5″	4′8″	1 630	22 000	72 815	0.425	3.130	76 370	McCreath, H 33.
Beaver Branch.									
Stirling, Powelton Coal & Iron Co.....	5′	5′	0.710	23 400	72.218	0 532	3 140	75.890	McCreath, H 34.
Moshannon, Moshannon L. & M. Co.	5′6″	5′3″	0.765	20.090	74.779	0.666	3 700	79.145	McCreath, H 35

* According to information kindly communicated by Dr. H M. Chance in anticipation of Report H_7, now in press, the Houtzdale and Beaver Branch coal-seam is now referred, by the Second Geological Survey of Pennsylvania, to the Freeport Lower or D coal, formerly known as the Middle Freeport (D′), instead of being referred to the horizon of bed B, the Kittanning Lower coal, formerly known as the Clarion, whose position is beneath.

Analyses of Upper Freeport or Lemon Coal-bed (E). Mainly Compiled from Reports H_2 and H_3.

NAME OF MINE.	Thickness. Gross.	Thickness. Net.	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Coke.	
CAMBRIA COUNTY.									
Coshun, Cambria Iron Co..........	4′2″	3′8″	0.160	18 630	74 950	1 400	4 860	....	By T. T. Morrell, Com. by John Fulton.
Dysart & Co., Lilly Station.........	5′0″	4′3″.	0.715	22.250	70.518	1.459	5.058	77 03	H_2, page 33.
BLAIR COUNTY.									
Bennington.									
Kittanning Coal Co (Juniata Coal Co)...	4′9″	4′2″	1.190	26 975	64 359	2.728	4.750	71 835	H_2, page 22.
Dennison, Porter & Co..................	4′10″	4′2″	0.960	26 400	65.586	2 274	4.780	72 64	H_2, page 23. M_2. page 46.
SOMERSET COUNTY.									
Hugus, Somerset...	3′9″	3′3″	0.860	16.885	66.055	0 585	15 615	82.255	H_3, page 163, upper workable bench 29″. Sample prob included bottom slates.
Rush, Lower Turkey Foot......................	......	2′6″	0.45	17.65	55.58	.....	26 77	......	H_3, page 254, anal. by P. Frazer, Jr.

Analyses of Somerset County Coals, by Andrew S. McCreath. Compiled from Report H_3 (1877).

NAME OF MINE.	Thickness. Gross	Thickness. Net.	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Coke.	
Pittsburgh Coal-bed, Salisbury Basin.									
Beachy, Upper bench	9′	8′	1 680	21 010	69.016	0.764	7.530	77.310	MM, 27, H_3, 83.
Wilhelm, Anspach & Co, Upper bench.	9′	8″	1.190	21 000	66 907	0.713	10.190	77 810	MM, 27, H_3, 81.
Yoder, West Salisbury	7′9″	7′2″	1.465	21.285	69 677	0 693	6.880	77 250	MM, 27, H_3, 80.
Livengood & Keim, Upper bench	.	7′	1.665	22.350	68 774	1.246	5.965	75.985	MM, 28, H_3, 80.
Keystone Coal & Manufacturing Co	9′	7′	1.050	19 610	70.239	0.761	8.340	79 340	MM, 28, H_3, 78.
Cumberland & Elk Lick Co.	8′6″	8′1½″	1 385	21.470	69 352	0.763	7.030	77.145	MM, 28, H_3, 75.
Saylor Hill	9′	3′4″	1.630	19 965	66.510	0.775	11 120	78 405	MM, 28, H_3, 76.
Barren Measure Coal-beds.									
Berlin Coal-bed, Blue Lick Valley.									
W. G Walker, (Upper)	4′	3′	1.945	21.935	68.544	1.161	6.405	70.120	M_2, 32, H_3, 39.
H. Coleman, (Upper) Standard Coal Co	3′10″	3′5″	2.010	20.535	68.321	0.744	8.390	77.455	M_2, 32, H_3, 33.
S. P Fritz, (Upper)	4′9″	4′4″	1.625	22.700	67.467	0 803	7 345	75 615	M_2, 32, H_3, 34,
Weighley (Lower) (Platt Coal)	4′2″	3′2″	1 000	18.175	53.521	5.384	21.920	80.825	M_2, 33, H_3, 31.
Price Coal.									
T. Price, Berlin	4′	3′	0.870	20.330	68.944	1.176	8.680	78 800	M_2, 34, H_3, 27.
Philson Coal (Rose).									
P. & B. Coal, Coke & I Co, Ursina (Lump)	6′	6′	0 920	22 950	66.999	3 096	6.035	76.130	M_2, 36, H_3, 249
P. & B. Coal, Coke & I. Co., Ursina (Slack)	6′	6′	1.555	23.480	63.483	4 037	7.445	74.965	M_2, 36, H_3, 249.

Lower Productive Coal-measures, Somerset County.

New Notation of coal-bed.	Old Notation.	NAME OF MINE.	Thickness. Gross	Thickness. Net.	Water.	Volatile matter.	Fixed carbon.	Sulphur.	Ash.	Coke.	
		Somerset Sub-basin.									
C′.	D.	Trevorrow's, Stony Creek........	....	3′3″	0 670	14 530	74 800	0 635	9 365	84 800	H_3, 117, Com for Steam and Rolling Mill.
C′.	D.	Wilt's, Stony Creek	3′11″	2′10″	0.600	15.415	70 632	1.748	11.605	83 985	H_3, 127, Upper bench
C′.	D.	Reitz, Stony Creek........	4′6	3′6″	0 940	19 060	70 659	1 291	8 050	80 000	H_3, 131
	B.	Zimmerman's, Fairview	4′	3′8″	0 630	15 565	67.420	3 590	12 795	83 805	H_3, 154, Imperfectly sampled.
C′.	D	Nicholson, Castleman River	6′6″	4′	0 84	19.82	71 32	1.53	6 49	...	H_3, 201, Upper bench = 2′
C′.	D.	Nicholson, Castleman River	....	..	0.50	17 66	51 43	3 11	27.30	...	H_3, 201, Lower bench = 2′.
C′.	D.	Nicholson, Castleman River.	5′6″	3′3	.	22 74	67 09		10 17		H_3, 201, Upper bench = 2′.
C′.	D.	Heinbach, Castleman River..	...	....	0.780	20.540	69 580	2 140	6 960	.....	H_3, 202, Upper bench = 2′.
		Johnstown Sub-basin.									
C′.	D.	Pile, Quemahoning Creek............	4′5	4′	0 950	16 540	71 206	2.409	8 895	...	H_3, 232, From slaty, lower bench.
C′.	D.	Beam (Lohr), Quemahoning Creek .	4′8″	4′	0 820	17.235	74 881	0 519	6 545	..	H_3, 230, Upper bench 4′
C′.	D.	Croll, Brown Run, Upper Turkey Foot	2′1	1′11″	0 55	21 90	60 98	0 62	15 95	...	H_3, 255, P Frazer, Jr [test for sulph
C′.	D.	Hanna, Harnedsville	...	3′	0.041	25 24	61 14	trace	13.21	......	H_3, 267, P. Frazer, Jr, Probably only ash
C′.	D.	McClintock, Harnedsville	3′6″	.....	0.035	22 25	73 08	0 81	2 71	.	H_3, 268, P Frazer, Jr, Upper bench 2′
C′.	D.	McClintock, Harnedsville.......	..	...	0.30	19 64	66 74	6 28	7 34	..	H_3, 268, Lower bench 1′.
	B.	Liston, Listonville.......	4′2″	..	0 910	21 960	64 597	2 298	10.235	..	H_3, 270.
		Berlin-Salisbury Sub-basin, North of Castleman River.									
	A?.	Heinemeyer.......................	5′10″	5′8″	0.600	26.000	55 683	2.167	15.550	73.400	H_3, 15, Sampled by owner.
C′.	D.	Wigle's, Garrett, Castleman River ..	6′	4′6″	0 850	16 850	69 578	2 587	10 135	82 300	H_3, 53, Sampled by owner.
D.	D′.	Wigle's, Garrett Coal Co.........	3′2″	2′10″	1.020	17.135	60 679	0.676	14.490	81 845	H_3, 54, Probably includes bottom bench.

IMPROVEMENTS IN COAL-WASHING, ELEVATING, AND CONVEYING MACHINERY.

BY S. STUTZ, M.E., PITTSBURGH, PA.

THREE years ago, at the Philadelphia meeting, in February, 1881, the author had the pleasure of presenting to the Institute a paper on coal-washing machinery.* Since that time many new machines, with important improvements and labor-saving apparatus, have been introduced, the construction and description of which may be of interest to some of the members of the Institute. By referring to the above-mentioned paper, and more especially to Plate IV., representing a vertical section of a coal-washer, it will be noticed that the bottom of the plunger-box *B* is made level or horizontal, and supports a spring-buffer *F* for the purpose of limiting the down-stroke of the plunger *P* and receiving the impacts of the latter. Although the construction of the box, in view of these impacts, received from the start the proper attention (the bottom of the chamber *B* being made of three thicknesses of 3-inch planks, resting on 6-inch square columns), yet, through careless working of the machinery, without the necessary water in the box, it proved in several instances not strong enough, and had to be changed. To prevent such interruptions in future, it became necessary to devise some means for relieving the machine from the impacts of the plunger altogether. This has been accomplished by the arrangement shown upon Plate I. of this paper, representing a new washer; and not only has the difficulty been overcome, but also some other advantages have been obtained, as will be seen further on.

The compartments *A*, *A′* of the separator-box have been set upon heavy cast-iron brackets *B*, leaving sufficient space below the bottom for the buffer *F* and the sediment-valve *K*. By means of the plunger-rod *b* passing through the stuffing-box *s* to the outside, and provided at its lower end with a shoe *a*, the impacts of the plunger are now transmitted from the buffer *F* directly to the foundation. At the same time a better guide for the plunger *P* in its up and down movement has been obtained. The plunger of the former machine had only the guide *I* and the yoke *Y*, whereas the new machine has an additional guide in the stuffing-box *s*, thus preventing wear and friction of the plunger against the lining of the box. Further-

* *Transactions*, vol. ix., page 461.

more, the mechanism for regulating the stroke of the plunger has been simplified in dispensing with the hand-wheel. The screw-nut *e*, swiveled to the yoke *Y*, is provided with a long thread to receive the upper end of the plunger-rod *b*, and is made of steel, sufficiently strong for all purposes. It is provided with four notches *n*, into which a piece of iron can be engaged; and, by turning to the right or left, the yoke *Y* is raised or lowered as may be required. Thus it is very easy to get the proper stroke for any kind of material, or to set the machine out of operation altogether, if necessary. With the exception of the gate *O* for the outlet of the impurities, the other parts of the machine are left the same as before. The bottom of the plunger-box being now inclined towards the sieve-chamber, less power or less weight of the plunger is required to produce the same action of the water as was obtained in the former machine. The operation of the present machine is the same as previously described. Fresh water is taken in through *G*, and the slack-coal, brought upon the sieve *S* by means of the chute *J*, is separated into coal and impurities, while passing from the rear to the front of the machine. The clean coal, delivered over the bridge *M* into the channel *C'*, goes to the elevator *E*, which brings it into storage-bins, while the impurities pass through the gate opening *O* into the chamber *W*, and thence through the opening *O'* to the trough *T*, where they are carried away by the action of the waste water. A number of the new machines have been erected during the last two years, and give full satisfaction in every respect. They are considered the best in the market, and offer the following important advantages:

1. The use of a differential cam for the working of the plunger allows to the material, after each stroke, the necessary time to deposit according to gravity. An eccentric or a crank cannot produce such a movement.

2. The use of valves between the plunger-chamber and sieve-chamber prevents the filtration and back-suction of the water during the upward stroke of the plunger, and thus saves the very small coal, which otherwise will pass through the meshes of the sieve and go to waste.

3. There is a saving of motive power in the working of the washer. The body of the water in the box *A* being divided by the partition *N*, the inertia of the small part above the latter has only to be overcome.

4. The current of the water produced by the plunger *P* not only lifts up the material upon the sieve *S* to effect the separation, but

also moves the separated parts, coal and impurities, towards the delivery-bridge *M* and gate *O* respectively. This is especially valuable, since the continuous and regular separation of material containing heavy impurities, such as iron pyrites, fire-clay, etc., is assured.

5. There is great economy of water. In the older machines the separated coal is floated out of the apparatus at the expense of an enormous volume of water; yet the impurities have to be removed from the sieve by the shovel, thus interrupting the working of the machine and making it intermittent and wasteful.

6. The forming of a special receptacle below the partition *N* allows the fine particles of pyrites, slate, etc., falling through the meshes of the sieve, to settle. Thus the clean water is not mixed with the slimy sediments, and the latter are not forced back again into the material.

7. This machine has greater capacity per square foot of sieve-surface, with less water, than any other in use. An apparatus of, say, two sieves, 3 feet by 4 feet 9 inches, or 28½ square feet surface, can wash properly from 200 to 250 tons of coal per day of ten hours with from 300 to 500 gallons of water per ton of coal, according to percentage of impurities, or about 7 to 9 tons per square foot of sieve-surface. The cost of washing will be from 2 to 5 cents per ton, according to locality and arrangements.

Elevators.—The hoisting or elevating apparatus is, especially as a labor-saving device, an important part of the washing machinery, and requires close attention. Its object is first to bring the material to be separated to the machinery, and afterwards to deliver the different parts to storage-bins or cars. For handling minerals or heavy substances, the elevators are usually composed of endless chains and buckets, caused to move around polygonal pulleys or sheaves. A steady movement without jerking or slipping of the chains is very desirable. Chains formed of common flat iron links render such a movement difficult and often impossible, no means being provided to prevent slipping. The apparatus shown on Plates II. and III. gives great satisfaction, and insures a steady and continuous working. The chains are composed of malleable iron or steel links specially designed for the purpose, and connected by means of rivets or bolts and nuts. Each link is provided with lateral projections, *r*, which regularly, at the proper time, are taken up by corresponding teeth, *t*, of the polygonal sprocket-wheels, *P*, as shown by Figures 1 and 2 of Plate II. Thus the chain is carried around with the

wheels, perfectly secured and maintained, no slipping or jerking being possible, till it arrives at the rear, where it is developed again and set free. Rods, *h*, reaching across from one chain to the other, support the buckets *k*. They are kept in place by screw-nuts and pieces of gas-pipe *o* inserted between the links and the buckets. According to the dimensions of the latter, links are made of different sizes and length. Figures 3 and 4 represent 8-inch and 6-inch links, with either two or four lateral projections *r*. They are always well-proportioned, and have large wearing-surfaces at their connecting-points. The sprocket-wheels *P* have independent angle-pieces, *m*, with their teeth, *t*, which are riveted or bolted to the sides. The teeth may also be cast with the wheel in a single piece, as shown by Plate III. The upper pillow-blocks, supporting the sprocket-wheels and the chains, are fixed movably upon guide-plates, *C*, and can be lowered and raised by means of the set-screws *s*. Elevators may receive an inclined or vertical position, or a combination of both together. The inclination of the apparatus on Plate II. is 60 degrees, with half-bushel buckets attached to 8-inch links. It receives movement by the pulley *D*, and takes the material from the bin *G* to the delivery-chute *F*. The ordinary speed is about 15 revolutions per minute, and the capacity, with seven-sided sprocket-wheels, $\frac{7 \times 15}{4} = 26\frac{1}{4}$ buckets $= 13$ bushels, or about 300 tons per day of ten hours. With a speed of 20 revolutions per minute such an apparatus can hoist and deliver 400 tons of material per day of ten hours. An elevator raising its load vertically is illustrated upon Plate III. It has quarter-bushel buckets, attached to 5-inch links, and is caused to move around twelve-sided sprocket-wheels *P*. The links and buckets are connected in the same way as previously described, and their form and dimensions only are different. But a special mechanism for delivering the material has been added to the wheels. As the receiving-trough or chute *C* has to be set outside the return passage of the buckets *k*, the material emptied out of the latter would not be delivered, but would fall on the back of the preceding bucket, and down again to the bin *G*, but for the additional mechanism. For this purpose, the inclined planes *c* are fixed between the sprocket-wheels *P* in such a manner, that turning around with the latter, between the chains, they invariably mesh in in front of each ascending bucket, and precede the latter to the delivery side, where they first receive the material, to let it slide afterwards into the receptacle *C*, as may be seen from the drawing. Their object,

therefore, is to bridge over the space between the receptacle and the buckets. This method is far preferable to the one frequently used, consisting in the run of the elevator at high speed, whereby the contents of the buckets are drawn over into the receiving chute. Of all the systems employed, that certainly is the worst, since it renders necessary the frequent renewing of the chains.

A mixed system of elevators, which is working very satisfactorily, is shown upon Plate V. It is vertical in its lower part and inclined at 60 degrees on top for the convenient delivery of the material. Instead of running both chains inclined, the return-chains only are often bent below the top wheels to bring the receptacle near enough, but this requires larger wheels and increases friction. Most of the power necessary to drive elevators is consumed in overcoming friction. It is advisable to make the links forming the chains as long as is reasonably practicable, consistently with the buckets or pans of the apparatus. For supporting and guiding the upper or ascending chains between the wheels, short pieces of angle-iron and stationary friction-rollers are preferable to loose and movable rollers. The latter are expensive to keep up, and make the chain too complicated.

Conveyers.—Another great labor-saving apparatus for handling or carrying minerals and other heavy substances from one place to another, is the conveyer, represented upon Plate IV. It consists, similarly to the elevators, of endless chains, formed of pivotally-connected links, pans or plates, secured to and carried by the links, sprocket-wheels for driving the chains, and rollers for supporting and guiding the table between the wheels. A represents a framework of timber on which are mounted the shafts a a' journaled in pillow-blocks a''. Each shaft has two sprocket-wheels E supporting the endless chains C C'. The pillow-blocks of one of the shafts a a', or of both if desired, are set upon guide-plates g g', and made adjustable by set-screws s in order to tighten or loosen the chains. Projecting lugs or sprockets e are cast on the periphery-sides of the wheels, by preference one after the other side. These lugs are designed to engage the links of the chains and prevent the latter, by means of corresponding projections, r, Fig. 3, from slipping, in whichever direction the table may be caused to move. The links are of the same kind as previously described and used for the elevators, with an eye at one end and a socket at the opposite end adapted to receive the adjacent link, and a pair of projections r near each connecting end. At or near the centre of each link, a flattened base or attachment p is formed to receive the sheet-metal pans or plates m

of the conveying-table. The width of the plates is about equal to the length of the links. They are secured either by means of bolts and nuts or rivets. As is shown by the drawing, Fig. 1, the forward or leading edge of each plate overlaps the rear or following edge of the preceding pan. This is necessary, and of great importance to form and maintain a close and tight joint between successive plates while turning around the angles of the wheels. Waste of small coal or minerals, etc., is thus entirely avoided. As a means for guiding and supporting the table between the driving-wheels, friction rollers *n* reaching across the table are employed for the upper part and its load, while for the return or lower part, small malleable iron rollers, *n'*, Fig. 4, in any desired number, suitably mounted on metal frames, are fastened by rivets or otherwise to the upper or carrying face of the plates *m*. These rollers, in the under or lower passage of the conveyer, from wheel to wheel, travel or ride upon suitable stringers or beams *A* secured to the framework *A*. It is preferable to fasten them immediately over the carrying chains, in connection with the attachments of the links. Large tables, designed to carry heavy minerals, etc., require three or more chains to prevent bending or sagging of the pans in the centre. In order to hold the mineral or earth to be conveyed upon the plates of the table, side-boards *R* supported by brackets *d* are employed, as shown in Figures 1 and 2. The brackets are fixed to the timber of the frame *A*. Sufficient clearance must be provided between the lower edge of the sides and the upper surface of the conveyer-pans to prevent friction. If desired, however, the ends of the conveyer-plates may be bent upwards at an angle and serve the same purpose as the sides *R* in preventing the falling over of the mineral, etc., or in many cases guards may be omitted entirely. It is, however, preferable, when any provision of this kind is needed, to use the fixed side-boards *R*, because the pans are not loaded thereby, and they are also free from the liability to become choked or bent, so as to interfere with the proper working of the table. Provision for charging the minerals, etc., upon the table, may be made by means of hoppers, or otherwise, as will be shown hereafter.

Arrangement and Disposition of Elevators and Conveyers.—This part of the paper is intended to illustrate some of the many cases to which this kind of machinery may be profitably applied. Plate V. is a part of the coking-plant at the Long Run mine, New Bethlehem, Pa., and shows the arrangement of two vertical elevators *E E'* in combination with the conveyer *C* to bring the slack coal to

the washing machinery. On the left-hand side is the washer-building with the separator *A* at the ground floor and a 4-roll crusher *R* above it. Two railroad-tracks are in front of the building, one for lump coal or the run of the mine, and the other for nut coal and unwashed slack. The coal intended to be washed is collected in the hopper *H* to be fed into the crusher-rolls, by means of the conveyer *C*. The different apparâtus have been designed in view of handling 200 to 250 tons of slack coal per day. During the regular or normal run of the works all the slack may be easily taken away by the conveyer, but it often happens that railroad cars have to be loaded in a very short time, and, owing to the small capacity of the hopper *H*, it became necessary to provide for some additional storage-room. This has been accomplished by means of an auxiliary bin *B* between the tracks and the building, holding about 150 tons. Dumping and loading may thus be done at almost any rate of speed, the surplus slack being let into the bin, and does not interfere with the regular working of the machinery. The object of the two short elevators *E E'* is to hoist this coal up again, when needed, without any extra labor or additional expense. As long as the conveyor is supplied with coal from the hopper *H* the elevators are at rest. They receive motion from the shaft *a* by means of a counter-shaft *b* and cog-wheels *e e'*. Both are provided with friction-clutches *f f'*, operated by levers *l l'*, and may be run independently one from the other. Usually only one of them is at work at the time. The buckets *k* deliver the coal upon the inclined chute *c c'*, by which it goes to the conveyer, and thence to the separating machinery. The length of the table is 17 feet 6 inches between the centres of shafts, by 36 inches width. Its speed is only about 40 feet per minute. No side-boards or guards are used here. Two men attend to all the machinery, the machinist and his assistant.

Plate VI. represents a different arrangement from the former, which, however, has the same object in view, namely, the handling of the surplus slack, produced at certain hours of the day, without additional expense of labor. It is a part of the coking-plant at the Rochester mines, Dubois, Pa., with the coal-tipples in the centre, a large auxiliary slack-bin *B* to the right, and a part of the coal-washer building to the left-hand side. *E E'* are two inclined elevators to deliver the slack from below the screens. Their capacity is about 250 tons each per day of ten hours. While dumping coal into railroad cars at the normal speed, the elevator *E* leading to the washing-machinery is quite sufficient to handle all the slack pro-

duced, but the time allowed for unloading pit-cars is very irregular. In the morning, between the hours of 7 and 10 o'clock, relatively few cars are taken out of the mine, because this time is required by the miners to loosen the coal and get ready for the day's work. Most of the coal is loaded between the hours of 10 and 3 P.M., and dumping is usually very lively about noon. A greater amount of slack is then produced than the elevator *E* can take away. Before the erection of the second elevator *E'*, and the auxiliary storage-bin *B*, the surplus had been very troublesome, interfering with the regular working of the washer. Two boys and two mules were kept busy to haul a part of the slack to the dump and bring it back again afterwards. That such a system of working could not pay, is easily to be seen. After this had been carried on for some time, the writer was consulted, and proposed the arrangement shown by the drawing, viz., an additional elevator *E'*, taking the surplus slack into the storage-bin *B*, and a conveyer *C* to bring the same back again when needed, the mechanism to be arranged in such a manner, that either part may be worked independently, or both apparatus set out of motion. This has been carried out, and gives full satisfaction. The elevator is of the kind shown upon Plate II., with half-bushel buckets, and about 56 feet long between the shaft-centres. Provision is made for about 300 tons of slack. At the bottom of the bin *B* are three gate-openings *i* to let the slack out again upon the table of the conveyer *C*. The latter is located on the side of the elevator, and passes through the middle of the storage-room about 2 feet below its bottom. It is 54 feet 9 inches long, from centre to centre of shafts, by 24 inches width of table, and the same in construction as shown upon Plate IV. The necessary power to drive the elevator and the conveyer is obtained from the main shaft *a* of the washing-machinery, and, by means of the pulleys *p p'* and a wire rope, is transmitted to the counter-shaft *b*. The latter, by means of two sets of bevel wheels *w w'*, and an inclined shaft, running outside and along the elevator-post, transmits motion to the upper chain-wheels of the elevator *E'*. A second counter-shaft *b'*, also receiving motion from the shaft *b* through the spur-wheels *e e'*, gives motion to the conveyer. This is done by the pulleys *g g'* and a rubber belt. The pinions *e* and *w* are connected with the female parts of the friction-clutches *f f'* respectively, and receive motion only when the clutches are set in. As soon as the slack commences to accumulate before the buckets of the elevator *E*, the second elevator *E'* is started by setting the clutch *f'* tight. The surplus is then taken to the bin *B*

until its volume has diminished to that required by the washer. The clutch *f'* is now drawn out again, or the elevator allowed to run empty. To start the conveyer *C* the clutch *f* is pushed in, and, as the male parts of both clutchers are connected together, this will set the elevator *E'* out of motion. One or more gates *i* below the bottom of the bin are then slightly opened, to let the slack upon the table and back again to the foot of the elevator *E*. No extra labor is needed; the work is performed by the engine which runs the washing-machinery.

NOTE ON THE PRESENCE OF LITHIA IN OHIO FIRE-CLAYS.

BY PROF. N. W. LORD, STATE UNIVERSITY, COLUMBUS, O.

HAVING recently had occasion to make a series of analyses of fire-clays for the present Ohio Geological Survey, I found that the amounts of potash and soda determined indirectly by measuring the chlorides volumetrically did not "check" with those obtained directly. Investigation with the spectroscope showed the presence of *lithia* in what seemed very appreciable quantities. The examination was made of a considerable number of samples, and in every case this element was found, though in varying amounts, as judged by the intensity of the spectrum.

To guard against error from the impurity of reagents, the whole process was repeated, using the same reagents in corresponding amounts, but leaving out the clay. In no case did these "blanks" show lithia; hence the presence of this element in the clays seemed to be established conclusively. In the same series of analyses, titanic acid, in amounts varying from three-tenths to nearly two per cent., was found. The presence of titanium was first observed in the Ohio clays, nearly three years ago, in the examination of clays from Logan. The occurrence of this element is, of course, not unusual in clay, but I believe that none of the published analyses of Ohio clays give it; certainly none of the former Ohio geological reports speak of its presence.

The following analyses show both the above ingredients. They were made during the summer of 1883.

	1.	2.	3.
Combined silica,	39.03	37.92	29.22
Quartz sand,	15 50	13.80	31.34
Alumina,	27.88	30.10	24.97
Oxide of iron,	2.41	1.94	1.66
Lime,	0.42	0.62	0.63
Magnesia,	0 68	0 53	0.40
Titanic acid,	1.26	1.85	1.30
Potash,	3 31	2.74	0.28
Soda and lithia,	0.12	trace	trace
Combined water,	8.17	9 95	8.90
Moisture (at 100° C.),	.76	1 05	1.69
	100.66	100.50	100.39

NOTE ON SOME HIGHLY PHOSPHURETTED PIG IRONS.

BY PROF. N. W. LORD, COLUMBUS, OHIO.

THERE have been made at one or two places in Ohio, during the last year or two, some irons of rather unusual phosphorus-percentages.

The first of these which I had occasion to examine came from Moxahala Furnace, in Perry county. The furnace was built originally to smelt an ore found in large deposits near its furnace in the "black band" horizon. The deposit was easily exposed by simple "stripping;" it was from six to eight feet thick, being a blue carbonate ore, very free from silica. This ore yielded, on analysis, from two to 3 per cent. of phosphorus, when carefully sampled.

The furnace company had trusted entirely to old analyses made on "outcrop" ore, well weathered, and received all other results with indifference. The result of the first run of the furnace was an iron in large whitish-gray crystals, and so brittle that it could be pulverized in a mortar. This iron contained 4.90 per cent. phosphorus. A limited quantity only was made, which was gradually disposed of as a great "softener" to foundries. The Moxahala Furnace was subsequently run on Lake Superior ore mainly.

The second case of such iron occurred last summer at Mt. Vernon Furnace. A deposit of what was locally known as "Hallelujah" ore, was opened for the furnace. This ore was a blue carbonate, similar to the first-described.

The iron made was pure tin-white in color, and showed large crystals without a trace of the grain of ordinary pig-iron. It was supposed at the furnace to be spiegeleisen, and was sent to me to be

examined for manganese, of which, however, it only contains a small amount. It, however, contains phosphorus, 4.30 per cent.; silicon, .05 per cent.

It is remarkable in its very low silicon percentage. This element was determined by Dr. Drown's nitric and sulphuric acid methods.

The iron contains no graphitic carbon, but dissolves completely in nitric acid to a brown solution. The carbon was not determined, owing to pressure of other work.

The above facts show that when basic steel-manufacturers want an iron with little silicon, and 4 to 5 per cent. of phosphorus, we can furnish it *ad libitum.*

SULPHUR DETERMINATION IN STEEL.

BY MAGNUS TROILIUS, MIDVALE STEEL WORKS, NICETOWN, PHILADELPHIA, PA.

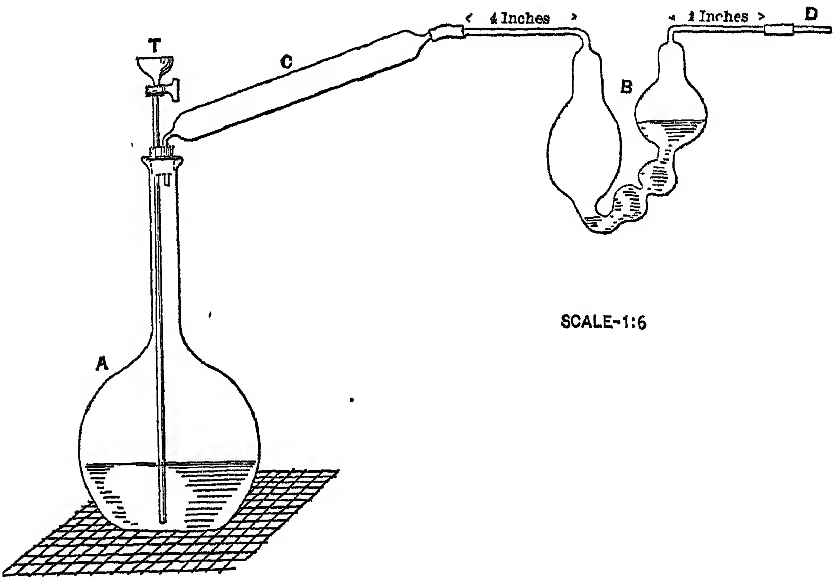
THE method of using the bromine process of determining sulphur in steel, described below, is in successful use at the Midvale Steel Works.

Ten grams of drillings are weighed out and put into the ½-liter flask *A*, with long neck. The flask is connected with a wide glass tube *C*, which, in its turn, is connected with the absorption bulbs *B*, containing HCl, 1.12 specific gravity, and about 5 c.c. of bromine. The wide tube *C* causes the vapor to condense and flow back into the flask *A* during boiling. The bulbs *B* connect with a long glass tube, which may be made to carry off the bromine fumes through a hole in a window, or, better still, through a flue with powerful draught.

The connections being made, 100 c.c. of boiling water are run in through the thistle tube *T*. The air is thus completely driven out of the flask. 100 c.c. of HCl (about 1.19 specific gravity) are then run in. When the gas begins to run rather slowly through *B*, heat is applied until boiling gradually ensues. The steel being completely dissolved, the apparatus is disconnected, and the contents of *B* rinsed out into a beaker of 100 c.c. capacity, into which a few c.c. of a concentrated solution of $BaCl_2$ have been previously introduced. Heat is then applied (best by means of the hot iron plate) until the bromine is completely driven off and the $BaSO_4$ has settled nicely to the bottom. The $BaSO_4$ is then filtered off on a small

double filter, washed with hot water, and finally ignited and weighed. The filter should always be put into the crucible whilst still wet.

The method now described is very rapid, and thus very useful in practical working, but it is at the same time scientifically superior to all other methods for determining the sulphur in steel as $BaSO_4$, there being no bases present by which the $BaSO_4$ can be contaminated. Even for pig-iron the method answers very well, no appre-



ciable amount of sulphur being left in the residue. As for sulphur being retained in the residue as CuS, when the amount of copper is considerable, this is a matter of rare occurrence, and the presence of 1 per cent. of copper or so would certainly be reason enough for a special searching investigation, not necessary during running work. A steel containing .30 per cent. of copper gave .16 per cent. of sulphur, both by the aqua regia* and the bromine method, and a spiegel with 9 per cent. of Mn and ½ per cent. of Cu gave traces of sulphur by both methods.

During the passage of the gas through *B* oily drops of propyl-bromide are formed, which, however, disappear on heating.

For working many determinations at the same time, it is convenient to have a large number of long-necked flasks, into which the different samples are weighed out, and a corresponding number of bulbs, filled and suspended in a row in a box of some convenient

* *Transactions,* 1881, p. 177.

form. The flasks should be perfectly dry before placing the drillings in the same.

Some chemists of standing say that the "bromine" method gives too low results, owing not to incomplete separation of the sulphur in the gaseous state, but to the formation of some combination with carbon, which cannot be retained by the bromine solution.

Whilst I, for my part, do not consider it likely that any such non-absorption would take place, I may add, that my own experience during two years of constant practice with the "bromine" and "aqua regia" methods has shown, that it is very difficult, particularly in the case of pig-iron, to obtain the $BaSO_4$ free from SiO_2, not to speak of other contaminations by the aqua regia method. If, to avoid this error, a very high temperature be used for separating the silica completely, SO_3 may be lost, and thus too low results obtained. The differences in results, when care and skill are used, are indeed not greater than would justify the conclusion that the higher results sometimes obtained by the aqua regia method are due to impurities contained in the $BaSO_4$.

TABLES FOR FACILITATING THE HEAT-CALCULATIONS OF FURNACE-GASES CONTAINING CO_2, CO, CH_4, H, AND N.

BY MAGNUS TROILIUS, MIDVALE STEEL WORKS, NICETOWN, PHILADELPHIA, PA.

THE heat-calculations of gas-analyses involve cumbrous multiplications, which are apt to lead into errors. The following tables and formulæ have been found useful as facilitating such calculations, and therefore I hope that they will be of interest to some of the members.

By "heat-unit" will, in the following, be understood the amount of heat required to raise the temperature of 1 kilogram of water 1° Cent.

All the tables refer to cubic meters at 0° and 760 mm. pressure.

The following gas is chosen as an example:

CO_2,	=	4.0	vol. per cent.
CO,	=	20.0	" "
CH_4,	=	3.5	" "
H,	=	7.0	" "
N,	=	65.5	" "
		100.0	

1. *Calorific effect*, or the number of heat-units that can be developed by the gas on complete combustion in pure air, containing by volume one-fifth oxygen and four-fifths nitrogen.

According to Bunsen 1 c.m. of CO at 0° and 760 mm. will thus develop 3007 heat-units; the same amount of CH_4, 8482 heat-units (the H_2O formed passing off at 100°); and the same amount of H, 2655 heat-units (H_2O passing off at 100°).

This gives us the following table :

Cubic meters	CO Heat-units.	CH_4 Heat units	H Heat-units.
1,	3,007	8,482	2,655
2,	6,014	16,964	5,310
3,	9,021	25,446	7,965
4,	12,028	33,928	10,620
5,	15,035	42,410	13,275
6,	18,042	50,892	15,930
7,	21,049	59,374	18,585
8,	24,056	67,856	21,240
9,	27,063	76,338	23,895

Thus for the above gas we find per c.m. at 0° and 760 mm.:

	Cubic meters.		Heat-units.
CO,	.20		601.4
CH_4,	.03	254.4	
	.005	42 4	
			296.8
H,	.07		185 8
			1084.0

Hence, W representing the total calorific effect per c.m. of gas burned, we find W = 1084.0 heat-units.

2. *Flame-temperature*, or the theoretical temperature which would result if all the heat W were utilized in raising the temperature of the nitrogen and the combustion-products only. In practice such a temperature is, as is well-known, never attained, owing to dissociation and other causes. But the calculation of said temperature is of interest for the comparison of a series of gases.

If T be the temperature sought, we have:

$$T = \frac{W}{CO_2 \times .425 + H_2O \times .382 + N \times .307}$$

In which equation the chemical symbols represent the volumes of the gases in the production of combustion, and

.425 = sp. heat per 1 c.m. CO_2, at 0° and 760 mm.
.382 = " " " " H_2O, " " " " "
.307 = " " " " N, " " " " "

all according to Bunsen.

For calculating T we make use of the following tables, remembering that by combustion in air one volume of CH_4 gives one volume of CO_2, two of H_2O, and eight of N; one volume of CO gives one volume of CO_2 and two volumes of N; one volume of H gives one volume of H_2O and two of N.

a. Of CO_2, originally present in the gas:

C.m. at 0° and 760 mm.		Heat-units.
1	takes up for each degree of temperature,	.425
2	" " " "	850
3	" " " "	1 275
4	" " " "	1.700
5	" " " "	2.125
6	" " " "	2.550
7	" " " "	2.975
8	" " " "	3.400
9	" " " "	3.825

b. Of N, originally present in the gas:

C.m. at 0° and 760 mm.		Heat-units.
1	takes up for each degree of temperature,	.307
2	" " " "	.614
3	" " " "	.921
4	" " " "	1.228
5	" " " "	1.535
6	" " " "	1 842
7	" " " "	2.149
8	" " " "	2 456
9	" " " "	2.763

c. CO_2 and N from combustion of CO, originally present in the gas. Each c.m. CO gives 1 c.m. CO_2 (sp. h. .425) and 2 c m. N (sp. h. .307). Hence the heat-units absorbed for each degree of temperature are for the product of:

C m. of CO burned.	Heat-units.
1, [.425 + 2 (.307)],	1.039
2,	2.079
3,	3.117
4,	4.156
5,	5.195
6,	6.234
7,	7.273
8,	8.312
9,	9.351

d. CO_2, H_2O, and N from combustion of CH_4 originally in the gas. Each c.m. CH_4 gives 1 c.m. CO_2 (sp. h. .425), 2 c.m. H_2O

(sp. h. .382), and 8 c.m. N (sp. h. .307). Hence the heat-units absorbed for each degree of temperature are for the product of:

C.m. of CH_4 burned.	Heat-units
1, [.425 + 2(.382) + 8(.307)],	3 645
2,	7 290
3,	10.935
4,	14.580
5,	18.225
6,	21.870
7,	25 515
8,	29 160
9,	32 805

e. H_2O and N from combustion of H, originally in the gas. Each c.m. H gives 1 c.m. H_2O (sp. h. .382) and 2 c.m. N (sp. h. .307). Hence the heat-units absorbed for each degree of temperature are for the product of:

C.m. of H burned.	Heat-units.
1, [382 + 2(.307)],	.996
2,	1.992
3,	2.988
4,	3.984
5,	4.980
6,	5.976
7,	6 972
8,	7.968
9,	8.964

Thus, for the gas in question, we find:

		Heat-units.
CO_2 = .040 c.m. (table *a*):		.017
N = .655 c.m. (table *b*):	.184	
	.015	
	.001	
		.200
CO = .200 c.m. (table *c*):		.207
CH_4 = .035 c.m. (table *d*):	.109	
	.018	
		.127
H = .070 c.m. (table *e*) ·		.069
		.620

Now, .620 being the heat-units absorbed for each degree of temperature by the total products (including nitrogen) of 1 c.m. of the gas, and T being W divided by this number, we have $T = \frac{1084}{.62}$ $= 1748°$ Cent.

3. *Calculation of percentage of carbon available* for combustion in the gas. We have, according to Bunsen, the weight of carbon per c m. of CO_2, CO, and CH_4, at 0° and 760 mm., as follows:

1 c.m. contains,	.5363 kg. of carbon.
2 " "	1.0726 " "
3 " "	1.6089 " "
4 " "	2.1452 " "
5 " "	2.6815 " "
6 " "	3.2178 " "
7 " "	3.7541 " "
8 " "	4.2904 " "
9 " "	4.8267 " "

Thus we find for our gas,

CO_2 = 04 c m., with	.021 kg. of carbon.
CO = .20 " "	.107 " "
CH_4 = .035 " "	.018 " "
Per c.m. gas,	.146 " "

The available carbon (that is, the carbon contained in CO and CH_4) is therefore $\frac{.125}{.146} = 85.6$ per cent. of the total carbon.

4. *Estimation of the amount of H_2O that passes through the generator undecomposed,* neglecting the hydrogen in the solid fuel.

According to Bunsen, one c.m. of H at 0° and 760 mm., weighs .0896 kg.; one c.m. of O, 1.4303 kg.; and one-half c.m. of C gas, .5363 kg. Bearing in mind that each c.m. of hydrogen unites with half a c.m. of oxygen to form water, we can frame for gas-analyses, like the one in question, the general formula:

$$\frac{(\text{c.m. H}) \times .0896 + \frac{1}{2}(\text{c.m. H}) \times 1.4303}{(\text{c.m. }(CO_2 + CO + CH_4)) \times .5363} = \frac{3 \times (\text{c.m. H})}{2 \times (\text{c.m. }(CO_2 + CO + CH_4))}, \text{ nearly,}$$

for the number of kg. H_2O decomposed per kg. of carbon. Applied to our gas, this would give

$$\frac{.07}{.275} \times \frac{3}{2} = .381 \text{ kg. } H_2O.$$

Suppose we know that our generator burns 800 kg. coke and evaporates 800 kg. H_2O in twenty-four hours: we find that 800 × .381 kg. H_2O = 304.8 kg. H_2O has been decomposed, and hence that 800 — 304.8 = 495.2 kg. H_2O must have passed through the generator undecomposed during twenty-four hours.

This calculation, although giving only the approximate value, may be of interest in connection with the practical working of gas-producers.

FURTHER DETERMINATIONS OF MANGANESE IN SPIEGEL.

BY GEORGE C. STONE, NEWARK, N. J.

SINCE the Troy meeting I have received several additional results of analysis of the same sample of spiegel, which I give below:

Chemist.	No.	Manganese Found	Method Used.
.P	47	13.03	Acetate, sulphide, and carbonate.
P	48	13 26	" " " "
P	49	13.72	Acetate and bromine.
P	50	13.10	Oxide of zinc, potassium permanganate.
P	51	13.10	" " " "
P	52	13.75	" " " "
P	53	13.69	" " " "
P	54	14.08	" " " "
P	55	14.02	" " " "
P	56	14.02	" " " "
C	57	13.68	Acetate and phosphate.
C	58	13 65	" " "
C	59	13 32	" " "
C	60	14.76	Potassium chlorate and phosphate.
C	61	15.04	" " " "
C	62	13 68	Potassium chlorate, bromine, and phosphate.
C	63	13 53	Potassium chlorate and phosphate.
C	64	13 68	" " " "
R	65	13.13	Pattinson's method.
R	66	13 63	Acetate, bromine, and phosphate.
S	67	13.36	Potassium chlorate and phosphate.
S	68	13.40	Acetate and phosphate.
T	69	13 21	Oxide of zinc, potassium permanganate.
T	70	13 02	" " " "
T	71	13.13	" " " "
T	72	13.21	" " " "
T	73	13.05	" " " "

P. I know only by correspondence. His methods are: for results Nos. 47, 48 (13.03, 13.26) dissolve in hydrochloric acid, evaporate, oxidize with nitric acid, filter from silica, separate iron as basic acetate, precipitate manganese as sulphide, dissolve in hydrochloric acid; and precipitate as carbonate. No. 49 (13.72) was obtained by Eggertz's method. Nos. 50, 51 (13.10, 13.10) were dissolved and oxidized as before, the iron precipitated by oxide of zinc, filtered and washed four times with cold water; and the manganese titered hot with permanganate. *P.* regards these two results as low. Nos. 52, 53 (13.75, 13.69) were dissolved and treated like the last two, the precipitated iron was again dissolved, separated, and titered as before; the results are the sum of the manganese joined in both

filtrates. Nos. 54, 55, 56 (14.08, 14.02, 14.02) were treated like the last, but the filtrates were combined before titering. *P.* says: "I have the utmost confidence in these three results, although they are much higher than any of the others, which may possibly have been due to a change in my permanganate standard, although I have no reason to believe such to be the case. . . . I tested the chemicals used." I am inclined to think, however, that his permanganate had changed, or else (as is usually the case) the oxide of zinc used contained manganese.

C. Since my original paper was written, C. has left me; and a sample on which the determinations here given were made was sent to him. Nos. 57, 58, 59 (13.68, 13.65, 13.32) were treated by the acetate and phosphate method as we used it at first. Nos. 60, 61 (14.76, 15.04) were treated by Ford's method. As the results were so high, and as he knew the asbestos used had been in the laboratory some time exposed to lime-dust, he suspected that lime had caused the trouble, and so repeated the determination in No. 62 (13.68), precipitating the manganese by bromine, before precipitating as phosphate. Nos. 63, 64 (13.53, 13.68) were treated by Ford's method, using asbestos that had been purified by washing with acid.

R. is a steel-works chemist. No. 65 (13.13) was made by Pattinson's method, in one hour and forty minutes; No. 66 (13.63) by the acetate, bromine, and phosphate method in four hours and thirty minutes. He writes: "I consider Pattinson's method to be the shorter, and to give sufficiently accurate results, although the acetate, bromine, and phosphate method will always be the most accurate."

S. is a steel-works chemist of several years' experience. His result No. 67 (13.36) was obtained by Ford's method; No. 68 (13.40) by the acetate and phosphate method, as C. and I have used it. Knowing that S. was in the habit of using Williams's method for manganese in steel, I asked him to try it on this spiegel; but he said it was of no use, since that method always gave too low results for spiegel; although he considered it accurate enough to check the working of a steel-furnace.

I. is the chemist of a large smelting and refining company. All his determinations were made by Volhard's method, as follows: Dissolve 0.5 grm. in nitric acid, evaporate to dryness, and ignite to decompose nitrates. Take up with the least possible amount of hydrochloric acid, and replace this by sulphuric acid, heating till copious fumes of SO_3 are evolved; dilute, boil, and add pure oxide of zinc to precipitate the iron; filter, wash, dilute to 500 c.c., take out at least two portions of 100 c.c. each, and titrate hot with potas-

sium permanganate, of about half normal strength, which has been standardized by iron. I. says this is the first time he has tried the method on spiegel, although he has used it frequently for ores. Nos. 69, 70, and 71 were made on one solution of the sample; Nos. 72 and 73 on a second.

In all there are now seventy-three determinations. Arranging them in a table, as I did for the former results at the Troy meeting, with the addition of two lines giving the number of determinations and the percentage within two-tenths of one per cent. of the average, and also a sixth column giving the totals, omitting the first class of methods, we get the following table. In this table I have omitted C.'s results Nos. 9 and 10 because they depend on another method, and C. 60, 61; D. 12; I. 19, 20, 25; M. 33, 34; N. 35, 36, 40, 41, 42; and P. 50, 51 because the chemists were not entirely satisfied with them. With these omissions there remain sixty determinations by eighteen chemists using twelve methods.

	FIRST CLASS. Williams's volumetric method.	SECOND CLASS Other volumetric methods.	THIRD CLASS. Methods in which the manganese is precipitated and weighed as phosphate.	FOURTH CLASS. Methods in which the manganese is precipitated as a basic salt and weighed as Mn_3O_4.	All methods.	Methods of the second third, and fourth classes.
Number of chemists using methods, . .	3	4	9	5	18	15
No. of determinations above 14 per cent.,		3		3	6	6
No. of determ's bet'n 13 and 14 per cent.,	1	10	24	4	39	38
No. of determinations below 13 per cent.,	7		4		11	4
Per cent. above 14, .		23		43	10½	12½
Per cent. between 13 and 14, ...	12½	77	86	57	70	79
Per cent. below 13, .	87½		14		19½	8½
Highest, ...	13.05	14.08	13.84	14.47	14.47	14.47
Lowest, ...	12.60	13.02	12.92	13.03	12 60	13.02
Average, ...	12.85	13.43	13.43	13.79	13.39	13.48
No. within 0.2 per cent. of average, .	7	0	12	1	16	21
Per cent. within 0.2 per cent. of average,	87½		43	14	28	44

My reason for adding the last column is that in the course of some experiments which Mr. Sands and I are now making to test the accuracy of the different methods of determining manganese we have obtained results which have satisfied us that Williams's method is not accurate, but gives too low results.

In the paper read by Mr. Mackintosh at the Roanoke meeting, he gives the results of some experiments made by reducing permanganate, taking up with strong nitric acid, precipitating by potassium chlorate, and determining the oxidizing power of this precipitate in terms of the permanganate used. Working in this way he obtained results which agreed very closely with the results calculated on the theory that the precipitate was MnO_2. It occurred to me that he had forgotten the possible influence of the foreign substances present in a spiegel (hydrocarbons and iron); to see whether these had any influence I repeated his experiments, adding 0.5 grm. spiegel before dissolving in nitric acid, and obtained the following results:

Spiegel used.	Permanganate added	Oxidizing power in terms of permanganate.	Deduct for precipitate from spiegel.	Oxidizing power of precipitate from permanganate.	Theoretical oxidiz'g power for MnO_2.	Per cent. of theoretical.	Theoretical oxidizing power for $10MnO_2MnO$.	Per cent. of theoretical.
Grm.	C.c.	C.c.	C.c.	C.c.	C.c.		C.c.	
0.5		24.49						
0.5		24.49						
0.5	25	33.58	24.49	9.09	10.	90.90	9.09	100.00
0.5	35	36 98	24.49	12.49	14.	89.21	12.72	98.19
0.5	45	40.60	24.49	16.11	18.	89.50	16.36	98.47

These results, I think, show that the foreign substances present do exert an influence, and that in the case of a spiegel the precipitate is very nearly $10MnO_2MnO$.

To test the correctness of Williams's method, I analyzed a sample of spiegel by it, using oxalic acid that had been standardized by iron wire (Williams's method), and also by standard spiegels (modified method). I then repeated the analyses on the same samples, adding to each, before dissolving, 0.2 grm. $Mn_2P_2O_7$ which I had prepared with great care, with these results.

Sample No.	Spiegel used	Manganese added.	Manganese found by Williams's method.	Gain.	Manganese found by modified method.	Gain.
	Grm	Grm.	Grm.	Grm.	Grm.	Grm.
1	0.5		0 10273		0.11037	
1	0.5		0.10273		0 11037	
1	0.5	0.07746	0.17434	0.07162	0.18749	0.07712
2	0.5		0.05370		0.05880	
2	0.5		0.05406		0.05934	
2	0.5	0.07746	0.12422	0.07052	0.13602	0.07722
2	0.5	0.07746	0.12565	0.07159	0.13759	0.07834

These results not only confirm the correctness of the volumetric method which Mr. Sands and I have used, but also indirectly confirm the acetate and phosphate method, as the standard spiegels used were analyzed by that method.

Mr. Sands and I are at present testing the different methods of determining manganese, and hope to publish the results when completed. We should be grateful for any suggestions as to doubtful points in any method that need clearing up.

NOTE ON THE DETERMINATION OF PHOSPHORUS IN IRON.

BY FRANK JULIAN, IRON MOUNTAIN, MICHIGAN.

After the solution of an iron ore, or metallic iron, in an acid, for the determination of phosphorus, it is necessary to evaporate the solution to dryness and to heat the residue to effect the complete separation of silica. Authorities differ as to the temperature required, some recommending not over 100° C., others as high as dull redness. For the purpose of securing some indications as to the degree of heat which may be safely or advantageously employed, I selected a gray pig-iron, a piece of Bessemer steel rail, and a sample of Ludington ore having the following composition; the phosphorus in the pig and steel being determined by Gintl's ferric chloride method:

	Pig.	Steel.	Ore	A	B
Comb. carbon, .	.64	.866	Silica, ...	3.30	sol. 1.00
Graphite, . .	3 40	. . .	Phosphoric acid, .	.0007	.400
Silicon, . . .	2 85	.077	Sulphuric acid, .	trace	
Sulphur, . . .	.06	. . .	Alumina, . . .	.79	
Manganese, . .	.51	.922	Lime, ...	.83	
Phosphorus, .	.459	165	Magnesia, . . .	.51	
Iron, etc., . .	92.081	97 970	Manganese oxide,	.62	
			Ferric oxide, . .	93.37	
	100 00	100 00			

Twenty-five grams of the ore, having the composition A, was dissolved in hydrochloric acid, and filtered into a ½-litre flask. There were added 3.1 grams of silicate of sodium and 1.155 grams crystallized phosphate of sodium, and the liquid made up to the mark.

Twenty-five c.c. of this solution, having the composition B, 1 gram of the pig, and 2 grams of steel, were taken for each determination. The metals were dissolved in 10 c.c. and 20 c.c. of nitric acid, specific gravity 1.25. After heating the dry residue, it was dissolved in the least possible quantity of hydrochloric acid, which was replaced by evaporation with 25 c.c. of concentrated nitric acid, and precipitated with a 7 per cent. nitric acid solution of molybdic acid. After solution of the phospho-molybdate the silica was separated, and any adhering phosphorus recovered. The magnesium precipitate was always reprecipitated to free it from molybdic acid (traces of which invariably adhered to the first precipitate), weighed as pyro-phosphate, and corrected for solubility. Great care was taken to have all the conditions of each determination as nearly identical as possible. The following are the results obtained:

No.	Temperature.		Pig.	Ore.	Steel.
1.	No evaporation.		. . . .	. . . .	.113, .124
2.	95° C.	1 hour.	.341	.407	. . . .
3.	110°	12 hours.	.375	.400	.137, .139, .132
4.	125°	1 hour.	.377	.401	.157
5.	170°	½ hour.	.444	.401	. . . .
6.	125°	2 hours.	.453	. . . .	. . . .
7.	170°	1 hour.	.456	. . . .	.158
8.	220°	1 hour.	.456	.398	. . . .
9.	350°	1 hour.	.453	.398	. . . .
10.	450°	1 hour.	.456	.398	. . . .

In No. 1 the steel was dissolved in acid, and the molybdic solution added at once. No. 2 was the heat of a water-bath; No. 3

steam-pipes; Nos. 4, 5, 6, and 7, an air-bath; Nos. 8, 9, and 10 fused-metal baths. The first four, in each case, dissolved readily and completely; Nos. 5 to 8, completely, but with difficulty; while Nos. 9 and 10 required much acid and a prolonged digestion, and a considerable quantity of ferric oxide remained undissolved.

While somewhat different results will undoubtedly be obtained from other samples, I think the following conclusions may be safely drawn:

1st. That a temperature of at least 125° C., for two or three hours, must be used where the amount of silicon or silicic acid is at all large.

2d. That any temperature short of dull redness may be employed without interfering with the accuracy of the determination; the heating with an acid reverting any meta- or pyro- into ortho-phosphoric acid; but that a temperature of from 125° to 170° is to be preferred, as saving time and acids in re-solution.

3d. That the silicon in metallic iron is much more prejudicial to the complete separation of phospho-molybdate than the silica from a soluble silicate.

NOTE CONCERNING A GRADE OF IRON MADE FROM CARBONATE ORE.

BY EDWARD GRIDLEY, WASSAIC, N. Y.

At the meeting of the Institute, held at Roanoke, Va., in June, 1883, I gave some facts in relation to charcoal pig iron of unusual strength, made from our carbonate ore taken from the mine at Amenia, N. Y.

My object in again bringing the subject to the attention of the Institute, is to obtain, if possible, the solution of a problem in connection therewith. Our furnace is of the old type, stone stack 32 feet high by 9 feet 2 inches at top of bosh; bosh about 67° pitch; stone hearth; three tuyeres of $3\frac{1}{2}$-inch opening; fuel, a mixture of hard and soft coal; blast about $\frac{1}{2}$ to $\frac{3}{4}$ pound pressure, and heated to 400° to 600° Fahr. by iron pipe oven on top of stack.

The analysis of the roasted carbonate ore, as before given to the Institute, is as follows:

Silica,	8.240
Peroxide of iron,	77.202
Alumina,	2.768
Red oxide of manganese,	3.005
Lime,	1.650
Magnesia,	1.167
Phosphoric acid,	.275
Sulphur,	.224
Loss by ignition,	5.684

Metallic iron,	54.042
Metallic manganese,	2.165
Phosphorus,	.120

The last week of our running, on $\frac{1}{3}$ Chateaugay and $\frac{2}{3}$ carbonate ore, we made No. 3 and No. 4 iron only—about 53 tons of No. 3 and 17 tons of No. 4. But as soon as our ore-charge was changed to all carbonate, the iron produced was nearly all No. 4.

The 583 tons made was graded as follows:

15 tons,	No. 3
442 tons,	No. 4
99 tons,	No. 4½
16 tons,	No. 5
11 tons,	No. 6

We tried repeatedly, by reducing the ore-charge, to make soft iron, at times getting the furnace hot enough to make white cinder; but in every case the iron was hard and close-grained.

Now, the questions I wish to ask, are:

1st. Why could we not make a soft iron?

2d. What shall we do to produce a soft iron from this ore?

3d. What is the cause of the high tensile strength?

I would add, that since the figures given at the Roanoke meeting, viz., 13 tests, showing average tensile strength of 41,349 pounds per square inch, we have had three samples turned from the pigs, and broken. In August last two were broken at Phœnix furnace, showing 43,003 and 42,450 pounds.

During this month one sample was broken at the works of the Thomas Iron Company, Hokendauqua, Pa., and reported to us by Mr. John Thomas at 48,400 pounds. Average of 16 tests, 41,962 pounds.

A PROCESS FOR MAKING WROUGHT-IRON DIRECT FROM THE ORE.

BY WILLARD P. WARD, A.M., M.E., NEW YORK CITY.

THE numerous direct processes which have been patented and brought before the iron-masters of the world, differ materially from that now introduced by Mr. Wilson. After a careful examination of his process, I am convinced that Mr. Wilson has succeeded in producing good blooms from iron-ore, and I think that I am able to point out theoretically the chief reasons of the success of his method.

Without going deeply into the history of the metal, I may mention the well-known fact, that wrought-iron was extensively used in almost all quarters of the globe, before pig or cast-iron was ever produced. Without entering into the details of the processes by which this wrought-iron was made, it suffices for my present purpose to say that they were crude, wasteful, and expensive, so that they can be employed to-day only in a very few localities favored with good and cheap ore, fuel, and labor.

The construction of larger furnaces and the employment of higher temperatures led to the production of a highly carbonized, fusible metal, without any special design on the part of the manufacturers in producing it. This pig-iron, however, could be used only for a few purposes for which metallic iron was needed; but it was produced cheaply and with little loss of metal, and the attempt to decarbonize this product and bring it into a state in which it could be hammered and welded was soon successfully made. This process of decarbonization, or some modification of it, has successfully held the field against all, so-called, direct processes up to the present time. Why? Because the old-fashioned bloomeries and Catalan forges could produce blooms only at a high cost, and because the new processes introduced failed to turn out good blooms. Those produced were invariably "red-short," that is, they contained unreduced oxide of iron, which prevented the contact of the metallic particles, and rendered the welding together of these particles to form a solid bloom impossible.

The process of puddling cast-iron, and transforming it by decarbonization into wrought-iron has, as everybody knows, been in successful practical operation for many years, and the direct process referred to so closely resembles this, that a short description of the theory of puddling is not out of place here.

The material operated on in puddling is iron containing from $2\frac{1}{2}$ to 4 per cent. of carbon. During the first stage of the process this iron is melted down to a fluid bath in the bottom of a reverberatory furnace. Then the oxidation of the carbon contained in the iron commences, and at the same time a fluid, basic cinder, or slag, is produced, which covers a portion of the surface of the metal bath, and prevents too hasty oxidation. This slag results from the union of oxides of iron, with the sand adhering to the pigs, and the silica resulting from the oxidation of the silicon contained in the iron.

This cinder now plays a very important part in the process. It takes up the oxides of iron formed by the contact of the oxidizing flame with the exposed portion of the metal bath, and at the same time the carbon of the iron, coming in contact with the under-surface of the cinder covering, where it is protected from oxidizing influences, reduces these oxides from the cinder and restores them to the bath in metallic form. This alternate oxidation of exposed metal, and its reduction by the carbon of the cast-iron, continues till the carbon is nearly exhausted, when the iron assumes a pasty condition, or "comes to nature," as the puddlers call this change. The charge is then worked up into balls, and removed for treatment in the squeezer, and then hammered or rolled.

In the Wilson process the conditions which we have noted in the puddling operation are very closely approximated. Iron-ore, reduced to a coarse sand, is mixed with the proper proportion of charcoal or coke-dust, and the mixture fed into upright retorts placed in the chimney of the puddling-furnace. By exposure for twenty-four hours to the heat of the waste gases from the furnace, in the presence of solid carbon, a considerable portion of the oxygen of the ore is removed, but little or no metallic iron is formed. The ore is then drawn from the deoxidizer into the rear, or second hearth of the puddling-furnace, situated below it, where it is exposed for twenty minutes to a much higher temperature than that of the deoxidizer. Here the presence of the solid carbon, mixed with the ore, prevents any oxidizing action, and the temperature of the mass is raised to a point at which the cinder begins to form. Then the charge is carried forward by the workmen into the front hearth, in which the temperature of a puddling-furnace prevails. Here the cinder melts, and at the same time the solid carbon reacts on the oxygen remaining combined with the ore, and forms metallic iron; but by this time the molten cinder is present to prevent undue oxidation of the metal formed, and solid carbon is still present in the

mixture to play the same *rôle*, of reducing protoxide of iron from the cinder, as the carbon of the cast-iron does in the ordinary puddling process. I have said that the cast-iron used as the material for puddling contains about 3 per cent. of carbon; but in this process sufficient carbon is added to effect the reduction of the ore to a metallic state, and leave enough in the mass to play the part of the carbon of the cast-iron when the metallic stage has been reached.

It would be interesting to compare the Wilson with the numerous other direct processes to which allusion has already been made, but there have been so many of them, and the data concerning them are so incomplete, that this is impossible. Two processes, however, the Blair and the Siemens, have attracted sufficient attention, and are sufficiently modern to deserve notice. In the Blair process a metallic iron sponge was made from the ore in a closed retort, this sponge cooled down, in receptacles from which the air was excluded, to the temperature of the atmosphere, then charged into a puddling-furnace and heated for working. In this way (and the same plan essentially has been followed by other inventors) the metallic iron, in the finest possible state of subdivision, is subjected to the more or less oxidizing influences of the flame, without liquid slag to save it from oxidation, and with no carbon present to again reduce the iron-oxides from the cinder after it is formed. The loss of metal is consequently very large, but oxides of iron being left in the metal the blooms are invariably "red-short."

In the Siemens process, pieces of ore of the size of beans or peas, mixed with lime or other fluxing material, form the charge, which is introduced into a rotating furnace; and when this charge has become heated to a bright-red heat, small coal of uniform size is added in sufficient quantity to effect the reduction of the ore. The size of the pieces of the material employed prevents the intimate mixture of the particles of iron with the particles of carbon, and hence we would, on theoretical grounds, anticipate just what practice has proved, viz., that the reduction is incomplete, and the resulting metal being charged with oxides is red-short. In practice, blooms made by this process have been so red-short, that they could not be hammered at all.

It would be impracticable in this process to employ ore and carbon in as fine particles as Wilson does, as a very large portion of the charge would be carried off by the draught, and a sticking of the material to the sides of the rotating furnace could scarcely be avoided. I do not imagine that a division of the materials into anything like

the supposed size of molecules is necessary; we know that the graphitic carbon in the pig-iron employed in puddling is not so finely divided, but it is in much smaller particles than bean or pea size, and by approximating the size of the graphite particles in pig-iron Wilson has succeeded in obtaining good results.

If we examine the utilization of the heat developed by the combustion of a given quantity of coal in this process, and compare it with the result of the combustion of an equivalent amount of fuel in a blast furnace, we shall soon see the theoretical economy of the process. The coal is burned on the grate of the puddling-furnace to carbonic acid, and the flame is more fully utilized than in an ordinary puddling-furnace, for besides the ordinary hearth there is the second or rear hearth, where additional heat is taken up, and then the products of combustion are further utilized in heating the retorts in which the ore is partly reduced. After this the heat is still further utilized by passing it under the boilers for the generation of steam, and the heat lost in the gases, when they finally escape, is very small. In a blast-furnace the carbon is at first burned only to carbonic oxide, and the products of combustion issue mainly in this form from the top of the furnace. Then a portion of the heat resulting from the subsequent burning of these gases is pretty well utilized in making steam to supply the power required about the works, but the rest of the gas can only be utilized for heating the blast, and here there is an enormous waste, the amount of heat returned to the furnace by the heated blast being very small in proportion to the amount generated by the burning of that portion of carbonic oxide expended in heating it, and the gases escape from both the hot-blast and the boilers at a high temperature.

In the direct process under consideration the fuel burned is more completely utilized than in the puddling process to which the cast-iron from the blast-furnace is subjected to convert it into wrought-iron.

The economy claimed for this process, over the blast-furnace and puddling practice for the production of wrought iron, is that nearly all the fuel used in the puddling operation is saved, and that with about the same amount of fuel used in the blast furnace to produce a ton of pig iron, a ton of wrought-iron blooms can be made. I had no opportunity of weighing the charges of ore and coal used, but I saw the process in actual operation at Rockaway, N. J. The iron produced was hammered up into good solid blooms, containing but little cinder. The muck-bar made from the blooms was fibrous

in fracture, and showed every appearance of good iron. I am informed by the manager of the Sanderson Brothers' steel works, at Syracuse, N. Y., that they purchased blooms made by the Wilson process in 1881–1882, that *none* of them showed red-shortness, and that they discontinued their use only on account of the injurious action of the titanium they contained on the melting-pots. These blooms were made from magnetic sands from the Long Island and Connecticut coasts.

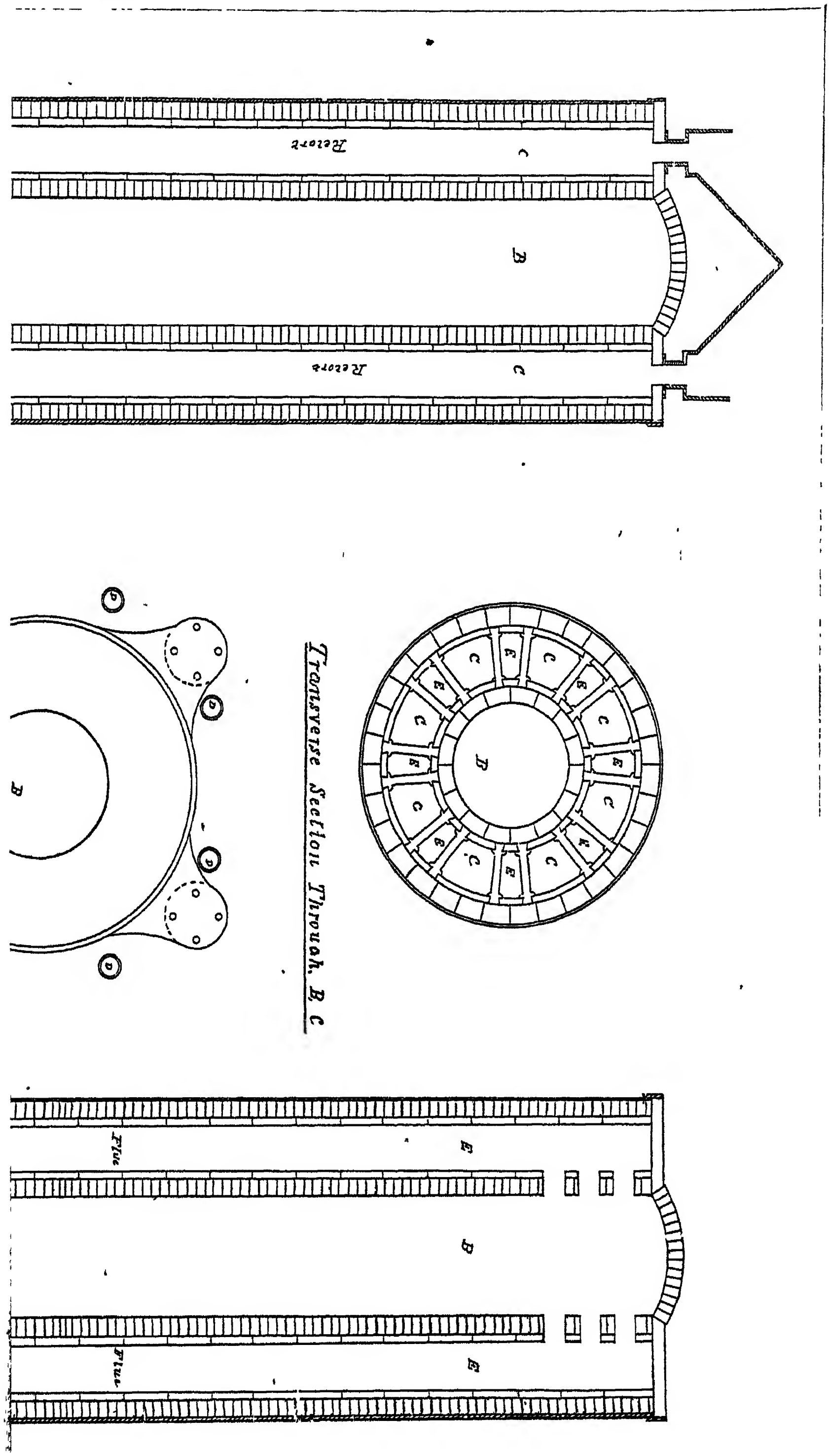
The annexed drawing shows the construction of the furnace employed. I quote from the published description.

"The upper part, or deoxidizer, is supported on a strong mantle plate, resting on four cast-iron columns.

"The retorts and flues are made entirely of fire-brick, from special patterns. The outside is protected by a wrought-iron jacket made of No. 14 iron. The puddling-furnace is of the ordinary construction, except in the working-bottom, which is made longer to accommodate two charges of ore, and thus utilize more of the waste heat in reducing the ore to metallic iron.

"The operation of the furnace is as follows: The pulverized ore is mixed with 20 per cent. of pulverized charcoal or coke, and is fed into an elevator which discharges into the hopper on the deoxidizer leading into the retorts marked C. These retorts are proportioned so that they will hold ore enough to run the puddling-furnace twenty-four hours—the time required for perfect deoxidization. After the retorts are filled, a fire is started in the furnace, and the products of combustion pass up through the main flue, or well B, where they are deflected by the arch, and pass out through suitable openings, as indicated by arrows, into the down-takes marked E, and out through an annular flue, where they are passed under a boiler.

"It will be noticed that the ore is exposed to the waste heat on three sides of the retorts, and owing to the great surface so exposed, the ore is very thoroughly deoxidized, and reduced in the retorts before it is introduced into the puddling-furnace for final reduction. The curved cast-iron pipes marked D are provided with slides, and are for the purpose of introducing the deoxidized ore into the second bottom of the furnace. As before stated, the furnace is intended to accommodate two charges of ore, and as fast as it is balled up and taken out of the working bottom, the charge remaining in the second bottom is worked up in the place occupied by the first charge and a *new* charge is introduced. As fast as the ore is drawn out from the


Retort
C
B
Retort
C
D
B
Transverse Section Through B, C
C
E
B
Flue
E
B
Flue
E

retorts the elevator supplies a new lot, so that the retorts are always filled, thus making the process continuous."

The temperature of the charge in the deoxidizer is from 800° to 1000° F.

THE PYRITES DEPOSITS OF LOUISA COUNTY, VA.

BY W. H. ADAMS, M.E., NEW YORK CITY.

VIRGINIA, a store-house of metals, is more and more a surprise to the present generation. With her enormous available mineral wealth, worked upon steadily for over a century, exploited sufficiently to demonstrate beyond question costs and values, reported upon by our most eminent scientists, written up by thoroughly earnest correspondents, we yet find her little understood by capitalists or practical men, and until very lately overlooked by the advance-guard of pioneers in metallurgy, whose restless energy conquered the wilderness of Northern Michigan years ago, and has written a new and startling history for almost impenetrable Western territories.

The world is learning through the mouths of giant furnaces lately put in blast at Lowmoor, Goshen, and Roanoke, more of this wonderful State. It is becoming plain that nearer home, amid all the surroundings of civilization, under an equable climate and with the advantage of a minimum cost for fuel and labor, there are stores of mineral, varied in character and deposited over a wide area, which exceed all ordinary calculations.

Principal among these minerals, iron ores have been, and will probably continue to be, the leading product and the source of greatest revenue.

My attention has been called during the past year to one particular section of the iron-belt, where for forty years charcoal-furnaces were successfully operated, the ores being mined in open pits, as can so frequently be seen from the Connecticut line southward into Georgia. There is, however, a significant peculiarity in the character of these deposits of Louisa county warranting special mention, as it is thought that nowhere on the earth's surface, within so moderate a distance of tidewater, can their like be found. Probably half a million tons of lump and wash-material have been taken from pits

within five miles of the Chesapeake and Ohio Railway station at Tolersville. These pits are from twenty to one hundred and thirty feet in width of all lengths up to fifteen hundred feet, the opening of which disclosed the fact that invariably at water-level the iron oxides cease and sulphides are found. As will be understood, the extent of the ore-bodies is enormous, millions of tons lying within a few hundred feet of the surface.

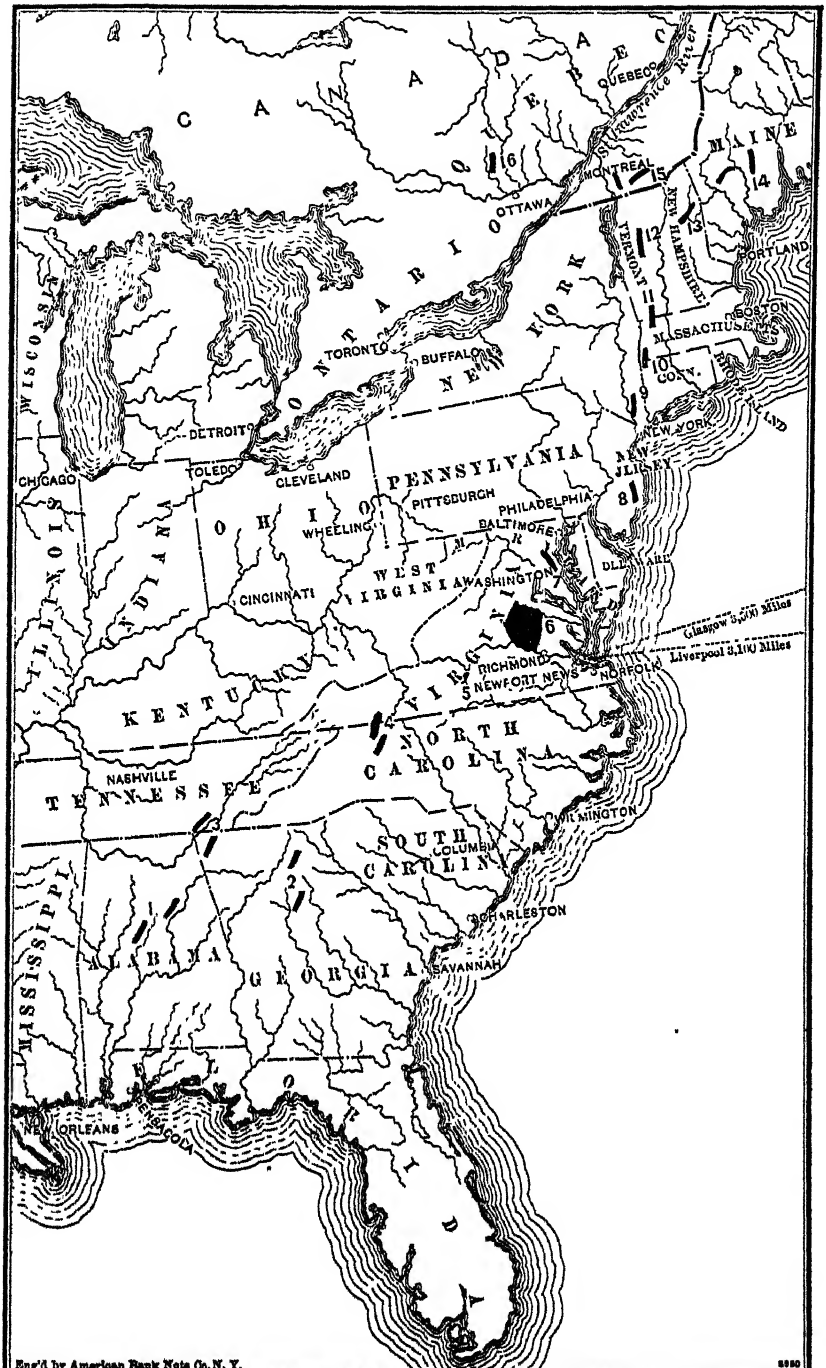
They no doubt belong to the general class of pyritous ores found along the Atlantic seaboard, in Georgia, North Carolina,* Virginia (near Lynchburg), Maryland (Cecil county), and New Jersey. The character of minerals changes thence northwardly, but the range of outcrops can readily be traced from Anthony's Nose, on the Hudson, through the mountains near North Adams, Mass., and north of the latter place, where there seems to be a division in the strata,—the eastern branch coming to the surface at intervals as far north as Milan, N. H., and into Maine, while the main branch is found in Vershire and Corinth counties, Vermont, and may be followed thence to the extensive deposits of Capelton and Bolton in Canada.

I wish to draw particular attention to the remarkable fact that although iron-ores outcrop continuously along the belt of country mentioned, yet only in the Carroll county beds on the border line of North Carolina, and in Louisa county are the deposits underlaid with pyrites of such character as to deserve special mention.

The object of this paper is to bring before the Institute the notable merits of pyrites from Virginia, at a time when the manufacturers of sulphuric acid are so rapidly changing their plant from brimstone-

* "The magnitude of the deposits of pyrites of iron and copper, with their valuable cap of hydrated peroxide of iron, entitles them to mention. Above water-level in the creeks and branches which cut across the strike of this great bedded vein every half mile or so, there is stripping ground fully 225 feet on the inclined face of the ore body. Measuring from the surface down, an average of 30 feet will be hydrated sesquioxide of iron, with crystals of copper carbonate in the lower portion. The next 3 feet will be oxide of copper and copper glance; the remainder, above water-level, or 192 feet, will be mundic or iron pyrites, with a variable proportion of copper pyrites containing on an average $2\frac{1}{2}$ per cent. copper and 45 per cent. sulphur, the residue mainly iron and gangue. A very considerable deduction has been made for intrusions of gangue, for the vein is sometimes 75 feet thick between its walls of talcose slates and schists.

"The body of pyrites in this length of fifteen miles, which has been thoroughly explored, may be claimed by a not unreasonable conjecture to be ten miles in length (one-third out for loss in ravines, etc.) by 192 x 33 feet." C. R. Boyd, "Ores of Cripple Creek, Va.," *Transactions American Institute Mining Engineers*, June, 1883.



Map showing Pyritous Deposits of the Atlantic States.

burning to pyrites-burning, and are asking for information as to sources of future supplies.*

The distribution of these and some other deposits is shown on the accompanying map, in which they are numbered as follows.

1. Birmingham, Alabama.
2. Copper mines, Georgia.
3. Ducktown, Tennessee.
4. Carroll county, Virginia.
5. Lynchburg, Virginia.
6. Louisa county, Virginia.
7. Cecil county, Maryland.
8. Zinc mines, New Jersey.
9. Anthony's Nose, New York.
10. Iron mines, Connecticut.
11. Rowe mines, Massachusetts.
12. Ely copper mines, Vermont.
13 Milan copper mines, N. H.
14. Copper mines, Maine.
15. Capelton, Canada.
16. Brockville, Canada.

It may, however, be interesting before leaving the subject of surface-ores of iron, to note the possibilities of utilizing, at no distant day, the very large deposits of hematites found throughout this section, which are available in part at present, and will be wholly so when proper drainage of underlying pyrites beds shall have been accomplished. In this connection I submit the following estimate of cost of making pig-iron, based upon statements of several well-informed parties, viz.:

2¼ tons of ore mined and delivered @ $1.50,	$3 37
1¼ tons coal or coke @ $3 50,	4 38
Limestone,	1 00
Labor, repairs, etc.,	3 00
Cost of one ton pig iron,	$11 75
Freight to tidewater,	75
Total,	$12 50

In itself this statement is sufficiently striking to merit attention, in view of the fact that Northern States are quoting a cost of over eighteen dollars per ton as an average.

The success attending the enterprises first mentioned, and further south on the same general belt, warrant the belief that in the near future, pig-iron can be produced and sold on tidewater at a profit in the Southern States for about the cost of production in Pennsylvania.

As before remarked, the iron deposits of Louisa county are underlaid with sulphide of iron. I am led to believe that originally the entire deposit was pyrites, and that the subsidence of waters or

* There were, January 1st, 1882, in the United States only two manufacturers burning pyrites, and using 100 tons per day of Canada ores, in which they were interested. At this date about 400 tons per day are burned by eighteen works. In other words, there has been 300 per cent. increase in about two years.

elevation of land gave opportunity for those changes on the surface which percolating waters and attendant chemical decompositions invariably produce. The physical structure of the veins, as already developed, clearly indicate that movements must have taken place after the formation of pyrites, causing fissures, breaks, discolorations, etc. The cross-section of the vein at the slope of the Arminius mines, on the accompanying plate, shows partially the forces exerted, but no adequate idea can be formed of extremes of compression on the various strata without personal inspection of the underground workings.

The pyrites is found at this mine 60 feet from the surface, and to the 150-foot level is generally decomposed and granular in form, and permeated by water so heavily charged with iron and copper salts as to destroy pipes or tools in a few weeks. These waters have so far remained nearly constant in strength, and are evidently confined to distinct strata, as neither the foot nor the hanging slates yield other than pure water.

Geologically, these deposits lie wholly in the primary rocks, here consisting of gneisses and crystalline schists (micaceous, chloritic, and argillaceous), within boundary inclosing, say, three miles width by ten miles length, the course being generally northeast and southwest.

I cannot more correctly state the existing features of the district, mainly covered by the properties of the Sulphur Mines Company of Virginia and the Arminius copper mines, than by referring to the accompanying plate and by quoting Schönichen, who says, relative to Spanish and Portuguese mines (*Dingl. Journal*, clxx., p. 448):

"All the beds are within a belt of 5 leagues width by 30 leagues length. . . . . Prevailing rocks, clay slates and crystalline slates. Parallel to the granitic tract of the Sierra Morena, felsite porphyry and quartzite have broken through the slates, and only in the neighborhood of such dykes are the pyrites beds found. Their shape is that of large lenticular pockets in metamorphic clay slate, from 20 to 36 fathoms thick and extending to a length of 170 to 200 fathoms. The whole bed is filled with pure pyrites without appreciable gangue. These beds are found in a few places at 2 fathoms below the surface undecomposed and in a sandy condition, easily got by pit-work. In other places the zone of decomposition reaches from 10 to 50 fathoms downwards."

These features are observable in Louisa county as distinguished from any other deposit known to me in this country. In addition,

the following table of analyses of ores from the several properties shows the most remarkable feature to be the absence of arsenic in every case, in striking contrast to ores from any other pyrites mines of magnitude in the world.

Analysis by Dr. A. Volcker, of London, June 30th, 1881.

Sulphur, ...	48.02
Iron, ...	42.01
Ferric oxide, ...	1.93
Sulphuric acid, ...	.44
Silica, ...	7.60
Copper, ...	none
Arsenic, ...	none
	100.

Analysis by Dr. W. H. Taylor, State Chemist of Virginia.

Sulphur, ...	46.40
Arsenic, ...	none

Analysis by Charles Tennant & Co., St. Rollax Chemical Works, Glasgow, June 3d, 1881.

Sulphur (dry) 50 per cent., or say Bisulphide of iron, .	93 8 per cent.
Siliceous matter, ...	6.2 "
Copper, ...	none
Arsenic, ...	none

Many analyses made in this country give results from 46 per cent. to 51.5 per cent. of sulphur, copper from 0.5 per cent. to 9.72 per cent., traces of gold and silver, but *in no case has arsenic been found.*

The following table of analyses is presented to facilitate comparison with the best known foreign ores:

	Sulphur.	Iron.	Copper.	Lead.	Zinc.	Lime and Magnesia.	Arsenic.	Insoluble.
Arminius Copper Mines,	49.27	43.62	1.50	...	0.38	1.32	....	4.23
Sulphur Mines Co. of Va.	50.	43.	...	...	...	....	....	6.02
Wicklow, Ireland, . .	38.79	36.06	2.57	1.80	...	....	.39	19.71
Norway, ...	47.55	41.92	90	...	1.26	3.38	....	6.15
Rio Tinto, Spain, . . .	47.87	40.93	3.82	.62	.10	.19	.26	5.42
San Domingo, Portugal, .	46.	43.50	3.10	1.60	.32	....	.30	5.18
Capelton, Canada, . . .	46.60	43.10	3.15	.45	.15	1.30	.15	5.10

The principal points to be established, in order to enlist capital in the proper development of such deposits, without which development there can be no benefit to the trade of the United States, are:

1st. Value of the pyrites.

2d. Extent of the deposits.

3d. Accessibility to markets.

Relative to the value of the material, I think scientific inquiry is fully answered by reference to the analyses already given, and commercially, the burning of many thousands of tons for the production of sulphuric acid during the past ten years has demonstrated this point beyond any question. In this connection an eminent chemist, and manager of the largest alkali-works in Great Britain, says: "There is no difficulty whatever in working Louisa county ore. It works much better than 'Tharsus pyrites,' *contains no arsenic*, and is, therefore, quite suitable for making pure acid for sale, and would replace for this purpose brimstone or Sicilian sulphur. Our furnace (Spence's mechanical shelf-burner) can do 25 per cent. more work with this than with 'Tharsus ore,' and I should be glad, indeed, if we could obtain materials of this class for our purposes here."

The well-known German chemist, Mr. William Barsch, of the Fairfield Chemical works, a gentleman of wide experience in burning all classes of foreign ores, pronounces these "exceptionally free from scar or clinker, the cinders coming from the kilns in as perfect a form as when charged;" and adds, "They give less than five per cent. 'smalls' or 'fines' in breaking to kiln-size, and do not decrepitate in firing."

Other disinterested testimony might be given, but is unnecessary, in view of the detailed analyses presented, and the fact that large amounts of ore are now being shipped to manufacturers of sulphuric acid, entering into direct competition with brimstone.

This may be shown practically as follows:

One ton of brimstone (seconds) costs in New York $26.00, and contains 98 units of sulphur, or say 26½ cents per unit.

Two and one-quarter tons of Virginia pyrites delivered in New York costs, @ $6.00, $13.50, and contains 98 units of sulphur saved, or, say, 13¾ cents per unit.

These facts are yet too little known among our manufacturers and scientific men. They are so plainly understood abroad, however, as to have changed the trade in manufacturing acids within the last fifteen years. Already over the entire continent of Europe the

price of acids, copper, purple ore, and even sodas is affected by the action of the combined pyrites-companies, who wield an influence equivalent to that of the oil-monopoly of our own country. There can be no possible competition between brimstone at its lowest obtainable cost, say twenty-one dollars per ton in New York, and pyrites with an equal sulphur-product, easily to be obtained at twelve dollars.

Copper must eventually be a source of income from these deposits. There has already been, in a desultory way, some developing of the copper-bearing portions of the veins, resulting in sales of perhaps $60,000 value.

The general similarity of the ores to those of Rio Tinto in Spain, would indicate that at greater depth a part will be suitable for copper-extraction.

The iron is, however, an element which in the near future must yield large profits.

By the "direct process" the residue, after extraction of copper and sulphur, can be converted into muck-bars at very low cost. This class of residual matter now sells readily in the markets, and will compete successfully with the better grades of foreign ores.

The gold and silver that almost invariably accompany this class of pyrites, may be commercially valuable, but have not yet been counted as factors of profit. Quartz-veins are found at varying distances from the main pyrites-veins, from which considerable gold has been recovered; and the beds of the creeks in the neighborhood have also furnished several hundred thousand dollars' worth of wash-gold during the last fifty years.

The extent of the deposits may be said to have been explored sufficiently to warrant contracts for, say, one thousand tons daily for many years to come. Machinery is now being put in, capable of delivering to the surface 500 tons daily, and when the branch railway is completed, reaching to the extreme end of the district, twice that amount can be delivered if required. The deposit shown in the accompanying plate, has the minimum width developed by either company mentioned, and will give a fair idea of the ease with which large quantities can be placed on the surface.

As to accessibility, it suffices to say that these mines are, in round numbers, 60 miles from tidewater at Richmond, and 130 miles from Newport News, Va. Both these cities are terminal points for the Chesapeake and Ohio Railway, and are fitted with coal-pockets, chutes, and all facilities for the transfer of ores direct to vessels.

Especially is this the case at Newport News, where 20 to 40 feet of water are obtainable, and berths for six vessels at a time, at the coal-wharves alone. The situation of this port on Hampton Roads, a land-locked harbor for the vessels of the world, with no ice or dangerous channels, permits freight to be secured at all seasons for coast ports, with but one handling from the mines. Owing to this very favorable location in proximity to cities of export for cotton and grain (the new elevator at Newport News stores 1,600,000 bushels of grain, and loads a vessel up to 100,000 bushels, inside of eight hours), it becomes possible for the Louisa mines not only to supply the trade at home, but to export the pyrites.

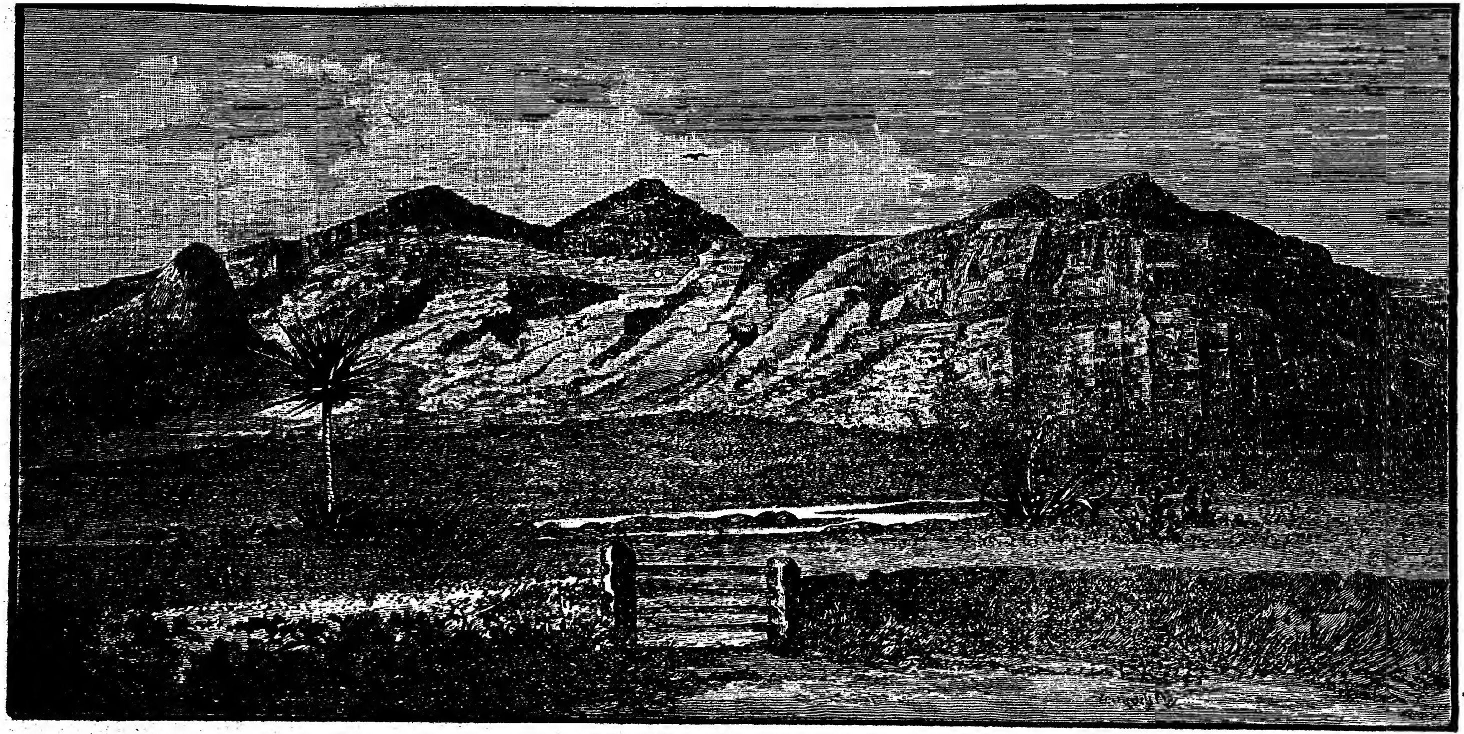
Liverpool is distant from Newport News 3100 miles. Glasgow is distant from Newport News 3500 miles. Havre or Bremen is distant from Newport News 3400 miles.

As ballast in cotton ships, ores can be shipped half the year for 2*s*. to 3*s*. sterling as against 14*s*. from Huelva, Spain, to England.

One-third of the cotton-crop of this country last year was loaded at Norfolk and Richmond. This insures all the tonnage necessary to transport ores abroad at minimum freight.

All inland cities within 500 miles from the mines will eventually secure their supplies of pyrites by means of railroads, in the same manner as coal or coke is now carried over long routes. The railroads are sure to underbid for this desirable class of freight, even to seaboard cities, if within reasonable distance.

The Institute may expect to hear more of this new mining industry through the developments and legitimate operations inaugurated on a liberal scale by the present companies, which operations must redound to the credit of the State, settle within her borders a new and busy colony, and bring into direct consumption large quantities of minerals heretofore considered commercially valueless.



View of the Sierra de Gomez looking southwest from the Hacienda of San Antonio. The position of the *Pinitos* mine is indicated by a round white spot in the centre background. The *Montaños* mine lies behind the central peak, vertically under the fish-hawk, and as far below the point where this line intersects the hill as the bird is above it.

CERTAIN SILVER AND IRON MINES IN THE STATES OF NUEVO LEON AND COAHUILA, MEXICO.

BY DR. PERSIFOR FRAZER, PHILADELPHIA, PA.

The mines which I am about to describe are all situated in the northern part of the States of Nuevo Leon and Coahuila, Mexico, between the twenty-sixth and twenty-seventh degrees of latitude. They might be grouped, orographically, into four classes: 1. Those in the Sierra de la Yguana chain; 2. Those in the Sierra de Gomez chain; 3. Those in the Cerro Mercado; 4. Those in the Sierra de San Márcos chain. (See large map.)

The first two of these may be further arranged in one geographical district, to which the name, "the Villaldama district," may be applied, and the last may be ascribed to the geographical district of "Monclova."

Geologically described, the country rock, in which four of the six mines occur, is a limestone, concerning which a few words will be said further on, to wit: The *Arroyo* (gulch), the *Montaños* and the *Pinitos* (pines), in the Villaldama district, and *La Paloma* (the dove), or *Iron Mine*, in the Monclova district.

The *San Rafael* appears to lie in granite, or a heavy-bedded gneiss, presenting most of the characteristics of the latter, though the contact plane of the limestone is not far off.

It is certainly worthy of attention that the ore occurs in that portion of the crystalline rock, which is nearest to the limestone, and it has been thought by some observers to be a true contact vein. It is well known that veins of this character are very often distinguished for constancy and richness. Although the undersigned cannot entirely free himself from the impression that this proximity of different formations has had an important influence in the origin of the part of the vein on which this mine is situated; still he was unable to establish it actually *at* the contact of the limestone and granite, but rather a short distance within the latter. Two openings of the *Riojas* vein were respectively in limestone and in rotten whitish granite, but this fact, if established (as by the correspondence of the strike line of the vein in direction with that of a line joining the

two openings, and the existence of an outcrop from one to the other it appeared to be), would only establish completely the independence of the fissure in which the vein was formed from this plane of contact, which it intersects obliquely.

Unfortunately, no systematic geological work has been done in Mexico, so far as the writer knows, and thus many questions, which could otherwise be at least provisionally settled by the analogies of similar occurrences in the United States, must be dealt with in another way.

The geological facts are that there is an enormously thick mass of limestone, which appears to form the greater number of mountain-chains in the district, of which I have given the boundaries, and down as far south as Monterey. On the Mexican National Railroad, just before reaching the station of Lampazos, one turns the end of the chain known as the Yguana, which extends to the river Sabinas.

This range of mountains (which has an average height above the plain of about 3000 feet, and above the sea of over 4000 feet) is composed exclusively of limestones, and throughout a great part of its extent it shows the most evident signs of metamorphism. It is most frequently of a drab or bluish-drab color; breaks with a conchoidal fracture and sharp, angular edges; contains very frequently cavities filled with crystallized, white calcite, and not unfrequently appears (*i.e.*, at *Piedras Pintas* or the "Painted Rocks") as a succession of heavy and thin, bluish and reddish layers, often weathered into the most fantastic forms (as in the cañon of the Portrero). This limestone has few of the characteristics which geologists are wont to associate with the great Lower Silurian limestone of the United States, the one particular in which it resembles and even surpasses the latter being its enormous thickness. From a few hastily-obtained, approximate data, taken in the Sierra de Gomez, near the Montaños mines, and presently to be considered, it appeared that this limestone is not less than 6000 feet, or a mile, in perpendicular thickness, and may be much more.

At present, the axes of the mountain ranges of the Sierra de la Yguana and the Sierra de Gomez are also the axes of anticlinals; the broad valley of Villaldama, therefore, representing a synclinal trough from the foot hills which lie N.E. of it to the latter range. The area between these same foot hills and the Yguana chain represents another smaller synclinal trough, and each is filled in with, probably, discordant rocks of a much later period. These are,

in turn, weathered as well as strewn with débris of a quite recent origin. (See Section Plate 1.) This, then, is the structure of this portion of Nuevo Leon as well as the writer has been able to ascertain it. The essential points are: 1st. All the rocks visible across this section are calcareous. 2d. The mountain chains which bound it on either side are the oldest formations exposed to view. 3d. They cover two anticlinals, and the correspondence of the dip of the rock with the slope of the mountain sides, and of the summits with the point at which the dip changes, are very striking. 4th. This limestone is enormously thick—more than a mile—and shows signs of metamorphism in a great many places where it was examined, leading to the belief that the strata composing it were at one time subjected to high heat and great pressure while deeply buried under sediments, which were torn away at a subsequent period.

5th. These limestone mountains are intersected by a great number of veins, of which calcite forms the principal material, though barite has also been frequently observed. Numbers of these veins are barren of the precious metals, so far as is yet known, but a large number carry argentiferous galena ores mixed with zinc blende, sometimes not in paying quantities. Lead, silver and zinc may not only be said to be the chief, but the only metals present in these ores, with the exception of the usual amount of all-pervading iron.

6th. The strike of these ranges is, roughly speaking, northwest and southeast. To be more accurate, the Sierra de la Yguana strikes W. 20° N.-(N. 70° W.), and the Sierra de Gomez, N. 25° W., whence it is readily seen that their respective axes are oblique to each other, and would intersect if produced across the larger valley of Villaldama at an angle of 50°. (See large map.)

They are evidently two radial crumplings of the strata, and if continuous would meet near to the settlement of Pájaros Azules in Coahuila, about the N.W. extremity of the short chain called the Sierra Madre (but no part of the chains known by that name either in the United States or just west of Monterey).

One physical feature which distinguishes the mountain chains of the limestone, is their general tendency to divide into a number of precipitous belts, of which one almost always forms the capping of the range and gives it a mesa-like appearance as if a mass of molten matter had been poured out upon a level surface and had been afterwards eroded or broken down by the subsidence of the strata on which it rested.

This comparison is, however, only used in a most general way,

as the columnar appearance of the narrow faces in the re-entrant angles of the mountain caps are only like the prismatic appearance of igneous rock when at a distance: on a near view these successive belts of thick limestone leave no possible doubt of their sedimentary origin, and show equally clearly that the fluted appearance is due to the general prevalence of cleavage planes, perpendicular to the surfaces of the strata. Nevertheless, the views which they present are very imposing, and together with the bold and rugged lines of the escarpment produce magnificent scenery. (See frontispiece. See also in this connection the handsome illustrations in Emory's Mexican Boundary Survey, and the view on the opposite page, from a photograph of the smelting works of the Pareña mine, in the Sierra Mojada.)

As will be found by reference to the tables of barometer levels, the Sierra de la Yguana is not so high a range as the Sierra de Gomez, or perhaps it would be more accurate to say that the portions of the two ranges which were visited differed in altitude by 2000 feet in favor of the Sierra de Gomez,* though this difference in height is not far from the correct one.

The age of this great mass of limestone is an important matter, even in an economical point of view, and great pains were taken to obtain fossils which would determine it, but the highly altered state of the limestone makes fossils very rare. Nevertheless, a few were obtained from the rocks on the slope of the Yguana chain, near to the Minas Viejas, the best of the very few specimens being found in the wall around the *jacal* (*pronounced "hakal"*).

Prof. Angelo Heilprin, of the Academy of Natural Sciences, Philadelphia, has had the kindness to examine these specimens at my request, and informed me that there were no remains well enough preserved, to enable one to be certain of the specific name, but that in general terms all the fossils belonged to the shell family *Aviculidæ*, and probably to the genera *Pterinopecten*, *Actinoptera*, and *Leioptera*. Unfortunately these forms existed from the later Silurian, through the Devonian and Carboniferous ages and into the Permian epoch. Prof. Heilprin, however, thinks that the fossils are more likely to be from the middle than from the extreme members of the series just named, in other words, they are Devonian or Carboniferous.

Prof. James Hall, the highest authority on the subject, was good

* Amidst the conflicting authorities for names of these mountains, the writer has fallen back upon the map of Nuevo Leon, published by D. Nigra de San Martin in 1853.

SMELTING WORKS OF THE PAREÑA MINE—SIERRA MOJADA—MEXICO.

1883.

enough to send me the following statement regarding the fossiliferous limestone fragments which I sent him, taken also from Piedras Pintas and Minas Viejas.

NEW YORK STATE MUSEUM OF NATURAL HISTORY, JANUARY 16TH, 1884.

DR. PERSIFOR FRAZER,

Dear Sir . . . .

The limestone you enclosed contains two or three fossils which can be recognized generally at least. Two of these are of *terebratuloid* character, and one *pectenoid*, probably an *aviculopecten*.

I infer from the character of these organisms as well as from the physical aspect of the rock that it is of the age of the carboniferous limestone series, which is so largely developed in the southwest.

The formation is essentially an extension of the great coal measures, but mostly destitute of the carbonaceous element.

I have, somewhere in Emory's report of the Mexican Boundary Survey, given my views of what I conceive to be the same limestone.* . . . .

Very truly yours,

JAMES HALL.

GUADALUPE STATION AND SMELTING WORKS.

This point, which is destined to play an important rôle in the future development of Northern Mexico, is now a flourishing little hamlet, distant about a league from Villaldama, and has been reclaimed from the desert appearance which the dryness of the soil away from the streams gives to this part of Mexico, by the untiring exertion and perseverance of Mr. Casper Butcher, aided by the able assistants whom he has had the discretion to call around him. One sees for a long distance in every direction over the flat valley the chimney of the smelter and the two shingle-roofed houses which constitute

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* The observations to which Professor Hall refers will be found in Vol. I., Part 2, pp. 122-125, inclusive, of the Report of the United States and Mexican Boundary Survey. William H. Emory, Washington, 1857.

The following, relating to the limestones northwest of the Limpia range, from p. 107 of the same volume and part, by the same author, will be found very interesting:

"Although these specimens present no well-marked fossil species, I am nevertheless quite convinced, from the character of the fragments preserved, that the rock is of the age of the upper carboniferous limestone. The condition and character of the rock with the fragmentary fossils is precisely identical with specimens from the neighborhood of the Great Salt Lake, and other western localities. They contain remains of small Terebratula in like manner: and the numerous fragments of organic bodies which cover the weathered surfaces, indicate sufficiently that the rock is, in a great measure, composed of similar materials. Some of the specimens are quite compact, and others are granular in texture; they are traversed by minute veins, sometimes of calcareous spar, and sometimes of harder material," etc.

The limestone here referred to is in all probability of the same age with that forming the Yguana, Gomez and St. Márcos chains.

the sleeping and dining departments of the settlement. In fact, from the summits of the mountains, twenty-five miles away, these buildings are the most prominent objects in the entire horizon. The description of the capacity and construction of the smelter does not enter into the purpose of this communication.

It will be enough, therefore, to say in this place that the smelter is designed for custom ores, *i.e.*, it is designed to take silver and lead ores of all kinds from the mines of the district, and reduce them for a stipulated price. This Fraser and Chalmers smelter is favorably located on the Villaldama river or creek (which is said never to be dry), and immediately on the Mexican National railroad, about one hundred and ten miles from Laredo, Texas, and sixty-six miles from Monterey. As a consequence of this, when the present very harassing administration* of the Mexican custom-house at Laredo, Tamaulipas, is ameliorated, as the writer is assured that it will be in a short time, machinery or materials for repairs can be telegraphed for and delivered from Laredo, Texas, at the smelter the same day. Similarly the routes for the transportation of ore from the *Arroyo* and from the *Montaños* and *Pinitos* mines are comparatively short and easy, and their carriage may be effected either in wagons or by an ore tramway as circumstances may justify.

The distance from Guadalupe Furnace, northeast to the *Arroyo* mine, is about sixteen miles in a direct line, and perhaps twenty-five miles following the direction that one is obliged to take. (See Sketch, Map No. 2.) The first two and a half or three miles to the low foot hills is a gentle ascent of only 225 feet which is hardly increased in the succeeding seven or eight miles to Piedras Pintas where the foot hills of the Yguana are first encountered. The entire distance up to this point is over a very gently undulating plain teeming with Nopal, Maguey, Lechugilla, and interspersed plentifully with the Palma Real. A road can be made in almost any direction over this plain, which is free from deep arroyos or acequias.† Even for the five miles or so which are traversed from the Piedras Pintas to the foot of the steep ascent of the main range, the rise is only 1500 feet or about 300 feet to the mile; which permits of an inexpensive road, being made to carry heavy ore carts, or of a mining tramway. An additional facility for the construction of either is found in the very numerous boulders and pebbles of hard limestone which are found in the bed of the gulch which leads up from Piedras Pintas between two

* December, 1883.

† Ravines or irrigating ditches.

spurs to the main chain of the Yguana. These permit repairs, filling, and embankment to be done with less cost than if the materials for such structures were only obtainable from a distance, or the rock massive.

Here, probably, the main road (if the transportation were by team to the Guadalupe Furnace) should terminate, although there would be no difficulty, except the expense, in the way of constructing a road either for wagons or tram-cars to the summit of the range. Questions of this kind cannot be definitely determined until the mines, on account of which they arise, have been more fully developed. From the head of the gulch the ascent is rapid to a certain cedar-tree on the western flank of the mountain which marks the junction of the trails to the mines from Guadalupe station or Villaldama, and from Candela. This cedar-tree is assumed in the absence of accurate data as about 1225 feet above the Piedras Pintas, or the mouth of the gulch between the spurs of the Yguana range. The altitude of this horizon above the sea is 3212 feet by uncorrected aneroid barometer, or 600 feet above the foot of the steep ascent. The rise from here to the crest of the range by zig-zag road is 1250 feet, this elevation being by the same instrument (and subject to the same errors) 4462 feet above sea level. As may be seen in this same very rough sketch the "Old Mines" or *Minas Viejas* now belonging to and owned by the Guadalupe Company lie beyond or east of the summit and about 400 feet below it in altitude. The *Arroyo* mine lies about northwest from the jacal, or walled domicile built for the accommodation of the workers of these mines, and is distant somewhere between three and four miles.*

Following a mountain trail from this jacal along the slope of the main range, and afterwards over one of the numerous spurs which jut out at irregular intervals on each side, one comes to a group of three mines situated on a vein (which is also said to be the same as that of *Minas Viejas*), belonging to the Guadalupe Company, and called the "*Buena Vista*," the "*Doctor*," and the "*Guadalupe*." The openings are passed in descending the steep sides of the gulch in the order just given, and by barometer they were respectively 3897, 3797, and 3517† feet.

* It is to be observed that the distances everywhere in this paper, except where otherwise specially mentioned, have been obtained by guessing.

† This level was taken on the return from the *Arroyo* mine. But just before taking the reading at the "*Doctor*," the barometer indicated a jump of 75 feet, and of course this correction was made.

The *Arroyo* is situated on the opposite side of the gulch and near the extremity of the spur into which it is driven. Its mouth has an elevation of 3230 feet above the sea or 250 feet below the last mentioned of the above group of three mines.

ARROYO.*

The entrance to this mine is an inclined drift, some eight or ten feet above the trail, by which it is reached, and from which access is had by the usual Mexican ladder, a notched tree-trunk.

The indications of a vein here are distinct enough, but, unlike the *Buena Vista* and the *Boca Negra* of the *Minas Viejas* group, the gangue is not calcite, and differs only in some characters from the surrounding limestone, which forms the country rock. What appears to be a cross-cut has been driven through barren limestone, until the vein was entered and the drift, changing its direction, in conformity with the latter, has penetrated, up to the present time, about ninety feet across the nose of the hill. The direction of the *Doctor* dump from the mouth of the *Arroyo* was, by prismatic compass, N. 38° W.; but this observation was necessarily a rough one on account of the great difference in level between the two points, which rendered it impossible for the eye to view the dump and the compass card at the same time. Moreover, the exact location of the dump from the mouth of the *Doctor* opening was not taken.

The dip of the vein in the *Arroyo* was about N. E.—65°, which would make it strike N. 45° W.; differing, therefore, 7° from the line joining the *Doctor* and the *Arroyo*. Nevertheless, on account of the prominence of the vein, and the frequently observed wavy strike-lines of the veins in this and other regions, it is thought most probable that both mines are on the same vein. After a slope of about ten feet in length through red dirt, a shaft of about ten varas† reaches the bottom of the excavation, and exposes a vein six feet in width.

This vein-matter is mainly a ferruginous limestone, but, like all the veins which the writer examined in the range, is destitute of well-developed walls. There seems to be an insensible transition from the barren, hardened limestone of the mountain to the reddish and often pulverulent material which constitutes the vein.

Between the walls of the vein and on the lower face are two

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* See Plate 3.

† The Mexican vara is equal to a length of 33.38 inches. Accurately 0.84796.

"horses" of barren limestone, which together make up about one-half of its entire breadth, or three feet. A careful section was made of the entire working face, including the horses, by knocking off specimens from every part of an imaginary line crossing it. This contained (as was feared) but a trace of silver, and very little lead.

The head-miner of the Guadalupe Company selected from the pay-dirt in this mine a specimen for analysis, and the assay of this sample in my laboratory was: Silver—$19.35; lead—$18.54; total—$37.89 per ton.

Nos. 3 and 4 were given to the writer by Mr. W. A. Butcher (see table of analyses on page 563) as samples of the ore of this mine; but it is not known from what part of the mine they were respectively taken, how they were selected, nor who selected them.*

No. 5 is an assay of a sample taken by the writer at random, from the dump of red ore in front of the opening to the *Buena Vista* mine, and analyzed for comparison with the ore of the *Arroyo*.

Making what allowance could be made for the angle in the drift, the average line of opening in the *Arroyo*, from the extremity of the drift to its mouth, is S. 42° E., which agrees within 4° of the direction of the Guadalupe mines, on the opposite side of the arroyo and 3° of the approximate strike of the vein given above.

Speculation as to the Mine's History.

The mine has doubtless been opened, and, in all probability, worked profitably for a time. Afterwards, it is likely that the pay-streak pinched, or that the vein became poor in the direction in which the drift was being pushed. The miners then came back from the extremity of the drift and sank the shallow shaft to which reference was made above. There are some signs remaining that this was also profitable for a time, but the bottom again approached the barren zone, which had been found above, and from some cause the work then was stopped, or, perhaps, the small excavations, oblique to the main drift, were made in the effort to find the lost "pay." Whether or not this purely conjectural version of the history of the mine be the real one, there is no doubt that the work was left where the ore failed, or was, at best, very lean, and years of neglect were allowed to add to this unfavorable ap-

* The analyses of various samples given to me by different persons as coming from the mines will be found in the table, along with those taken by myself.

pearance of things by the disintegration of the walls and breast and the gradual accumulation of débris. In this state it was examined.

The vein of the *Arroyo* is most probably the same as that which is now worked in the *Doctor*, the *Buena Vista*, and the *Guadalupe* drifts, above described, not to speak of the *Minas Viejas*, which are too far off to permit this statement without some necessary preliminary topographical work. But if not on the same vein as that of the latter, it is clearly an allied vein in the same mineral zone, and most probably connected with it both genetically and actually. The vein is wide (for the veins of this region), and as well defined as most of them, though it lacks the customary calcite gangue. It is well located for getting out what is found in the extremity of the space which it traverses, and would soon open 100 feet or more of stoping ground if properly exploited. It lacks the thick cover of the mines on the other side of the gulch, but contains enough to be worked actively to advantage when pay-ore is again found and followed.

Problem of Dressing Ores in the Absence of Water.

Two questions arise in connection with this mine which are of immediate importance. These are: 1st. The means of concentration; and 2d. the means of transportation. As to the first, it will be necessary to perform this, if possible, as near to the mouth of the mine as possible, in order to avoid the useless expense of a difficult transportation of worthless rock. But there is no water which may be depended upon for wet concentration. In revenge for the soft rock which can be cut for one-half, or less, what granite costs, the absence of water from this whole region is at once its chief characteristic and the greatest obstacle to its improvement. There is but one solution to the difficulty, and that is some form of dry concentration similar to that known as Paddock's.

This machine is well adapted to the work it will have to do here, viz., the separation of limestone and zinciferous galena, provided that a motor can be found. It is possible (not very likely it must be said) that somewhere in these foot-hills water could be got by artesian borings. If not, the water for a steam-engine would have to be hauled, and it would become a question of vital interest to know whether windmills, caloric engines, or the as yet visionary sun-engine of the great Ericsson, could not be employed here and in similar cases.

Transportation.

As to the transportation, it will appear from the preceding remarks that the plan which in all probability will be found the best for transporting the *Arroyo* ores to the Guadalupe furnace is by wire tramway from the mouth of the mine to the summit of the Yguana range, and thence either by a continuation of the same means to a point where the cart-road from the Guadalupe furnace reaches the mountain: or, it may be found feasible and convenient to transport the ore through a chute by its own gravity, from the summit to a pocket at the terminus of this cart-road, in which case so much power will be saved. The same remarks as to power which were made just now in connection with the concentrator and crusher apply equally to the wire tramway.

THE MONTAÑOS AND PINITOS MINES*

are situated respectively on the east and west slope of the Sierra de Gomez, and are reached by a comparatively level road from Villaldama southwest across the valley designated by that name to Potrero, and thence by trail for about 15 miles from the ridge to the mine. The grade from Villaldama to Portrero is very slight, the latter place being distant about eight miles, and lying at an altitude of only 75 feet above the former. The Hacienda de San Isidro del Potrero, as this flourishing little hamlet is called, forms a borough governed by an Alcalde, Juzgado, etc. The highly cultivated fields immediately around it are watered by the Potrero stream, which descends the mountain from the Hacienda of San Antonio, shortly to be mentioned. At the time of the writer's visit, December 1st and 2d, 1883, the sugar-cane was luxuriant and ripe, as well as the Maguey de Castilla, and many domestic plants. This fertility is an important factor in the problem of any future industry undertaken on the large scale, because it shows what the country could be made with intelligent tillage and irrigation. There is nothing in the soil underlying this settlement which gives it an advantage over the broad plains which stretch between these mountain ranges from Lampazos to Monterey, except what is gained from the water of the brook which bears its name, and the cultivation which this accidental advantage has invited. But the gardens bloom with all the ornamental and useful plants of this semi-tropical climate, and it would doubtless be easy to prove, statistically, that the hacienda as a farm has always been a commercial success.

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* See frontispiece.

A short ride across the valley southwest, brings us to the mouth of the Potrero stream, at a height of 1917 feet, while the town of Potrero is 1822 above sea-level. The road up this cañon is strikingly beautiful, winding among the sharp cliffs weathered into the most fantastic shapes which crown the stream. This last is collected into an artificial channel and directed by advantageous cuts from side to side across the little valley. A merely rough guess makes the Hacienda of San Antonio about eight miles from that of Potrero. Here is the site of a small Mexican smelting furnace, or *horno,* which, together with a crude apparatus for washing the ore, has been in use by the owner, Don Tomas Gonzalez Villareal, for the treatment of the *Pinitos* and *Montaños* ores. A plan of these works (Plate 4), together with the washing-pit, ditches, and stream outside of them, will be found at the end of this paper.

As will be seen, one end of the hut is taken up by the furnace, which is made by simply partitioning off a length equal to the desired width of the furnace. The in-walls are then obtained by adding refractory materials to the inside, and a tuyere-hole produced by cutting a hole in the partition. There is no chimney proper at present, and the fumes of the furnace probably found their way to the upper air with considerable irregularity.*

A rude water-wheel of the turbine family was so connected with a crank as to work a roughly constructed bellows which assisted the smelting.

The capacity of the *horno* is said to have been from 1½ to 2 tons per day, which is a fairly creditable practice for such an apparatus.

The stream which waters the hacienda, proceeds from three springs, distant about half a mile across a growth of low *palmas reales* and pine trees. These springs are evidently not true springs, but are most probably small streams which plunge into a mountain cavern some distance up the side of the mountain, and continuing subterraneously, issue at the place named. Their temperature is quite high, and almost immediately after their appearance, they form a volume of water equal to 1994 gallons per minute, which flows past the works.† The declivity of the hill east of the jacal and ore-

* For descriptions of the structure and duty of this kind of a furnace, see papers by W. Lawrence Austin, Phila., one in the *Transactions,* vol. xi., p. 91, and the other, read at Chicago, May, 1884, to be published in vol. xiii.

† This estimate is based on the average of a few experiments with floats. The distances were obtained by pacing, and the cross-section of the flowing water by means of a foot-rule.

house, is very steep, or about 25 feet in the first 100 yards to the east, or 80 feet from the works to the foot of the hill, distant perhaps twice as far. There is, therefore, evidently fall enough to use economically the power of this stream in a turbine wheel; though whether this would be a sufficient motor depends upon the amount of work required of it. It would not suffice for this purpose if the production of the *Montaños* and *Pinitos* mines should become large, and the water to wash the ores as well as the power to drive the machinery by water-wheel were sought in this stream; but it would amply supply all the water necessary for steam-boiler purposes, as well as that for the concentrators.

At this place there is a tree of the species known as the *nogal* (or walnut), very remarkable for its size, more especially so in the absence from these mountains, of large timber suitable for heavy mine timbering purposes. This tree measured 10 feet 6½ inches around the trunk, at a distance of five feet six inches from the ground.

The trees of this region are larger and more numerous than those observed elsewhere, but there are few suitable to the strain of supporting the roof of a flat vein.

From the southwest side of the Horno of Don Tomas Villareal, called San Antonio, one has a fine view of the mountains, and of the mouth of the *Pinitos* mine. The *Montaños* is hidden behind the highest as well as the most remote of the peaks in this part of the chain. (See frontispiece.) The position of the *Pinitos* is marked by a round white spot; that of the *Montaños* is as far below the point of intersection of a vertical line from the fish-hawk with the slope of the hill, as the bird is above this point.

The distance in a straight line from San Antonio to the *Pinitos*, is about one and a quarter to one and a half miles, and the elevation of the latter above it is about 2567 feet. The country immediately in front of the hacienda, and between it and the mountains, is a basin filled with rounded hills of comparatively moderate height.

The elevation of the *Pinitos* above the Horno is so considerable that there is no difficulty in solving the problem of getting the ore down to the latter. A single chute would probably suffice to effect this to the base of the hill, after which a wire tramway or other mode of conveyance would be needed to carry the ore to the works of San Antonio. The *Montaños* mine is at a considerable distance from the *Pinitos*, and over the divide. In order, therefore, to transport its ores as well, it would be necessary to carry them up a grade of 555 feet before they commenced the descent of 3820 feet, which

separates the San Antonio works from the summit to be crossed, and some method of continuous transportation from the *Montaños* to the *Pinitos*, would probably be found desirable.

PINITOS

is situated on one of the high slopes of the eastern part of the Gomez range, and, as before stated, about $1\frac{1}{2}$ to 2 miles from the Horno of San Antonio, in a straight line. There are two principal openings to the *Pinitos*, the regular and larger opening lying to the north of the other, which is newer.

This latter or southern opening is narrow and irregular (as are most of the openings to Mexican mines), and it runs back about E. 20° N. (neglecting the angles) for 80 feet.

The vein here, as has been noted elsewhere, is not like those fissure veins, of which the walls are defined, and mark the boundary between different rocks. Here the country-rock as well as the vein is limestone, but in the latter the limestone is stained with iron oxides, and is less hard and compact. The opening is about 5 feet high, and 4 feet wide. Don Tomas Villareal supposed that the entire vein contained ore. A great deal of calcite occurs here in the form of patches and strings, but not to the extent of filling the vein. According to the statement of the owner, Don Tomas Gonzalez Villareal, the ore from the working-face of this mine has assayed 18 marcos per carga. [A marco equals about 8 ounces, and a carga 300 pounds. This would equal about $1238 per ton of 2000 lbs.].

The present working-face of the southern opening reveals a crevice, which contains no visible ores in sight, though occasional patches of calcite of higher specific gravity than usual are found on the walls. An average of the gangue-mass at the extremity of this drift was taken, and proved to contain 1 ounce of silver ($1.29) to the ton.

A pocket has been dug out on the side of the trail, and adjoining the drift to the south. The ore exposed consists of red and yellow clays of high specific gravity, with an apparent dip of W. 10° S.—15°.

The main or northerly opening of the *Pinitos* exposes the vein more perfectly, with an average thickness of about 1 foot, and an average dip of ± N. 20° W.—45°.

The vein-matter consists of calcite stained by oxide of iron, and holding minute crystals of lead-minerals, which give it a higher specific gravity. This iron-stained gangue can be followed on either side for some distance, and several smaller veins or feeders can be observed to join it, but these latter are to all appearance barren; or

at least the minerals, which they possibly contain, are not in large quantity, and are masked by the material of the gangue.

In order to secure a good average sample of this ore, specimens were taken from all parts of the vein exposed, and they may be considered a fair exhibit of what the mine will produce in its present condition: The assay gave silver, 24 ounces; lead, 21.9 per. cent.; total value of ore per ton, $50.01.

The "cover" on the *Pinitos* is ample, and the facilities for extracting the ore, and transporting it to the works at San Antonio, could hardly be conceived better than they are. The ore also is less adulterated with zinc blende than the ores of the Sierra de la Yguana.

MONTAÑOS*

is situated, as stated before, on the westerly slope of the Sierra de Gomez, about four miles westerly from the *Pinitos*, and 550 feet below the summit. Between these two latter a number of veins are visible; one in particular, 7 feet wide, and striking northwest on the bold face of a cliff at the angle of one of the numerous turns which the trail makes over the mountain, was said not to have been "denounced"† on account of its barrenness. Another vein of this colored calcite, still nearer the *Montaños* property, strikes N. 20° W., and is about 5 feet in width. This latter coincided very nearly with the apex of the anticlinal of the mountain, or the point where the general dip of E. or N.E., which had characterized the exposures heretofore, was exchanged for one of W. to S.W. (in point of fact, S. 20° W.), and the massive limestone commences to descend into the western plain in the same manner, as on the eastern side, into the valley of the Villaldama.

The apparent analogy between the two valleys is even carried further by a series of low hills which occur in a position with regard to the great chains similar to those east of Guadalupe station. On the actual summit of the mountain anticlinal, the dip is S. 30° W.—18°.

But the little ridge in the middle of this western valley appears not to be an anticlinal but a monoclinal, conformable with and above this limb of the west-dipping mountains. In this case the thickness of the limestone from the face exposed at the crest to the lowest face which dips into the plain is not less than 6000 feet, and the actual thickness of the formation is much more.

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* See Plate 5.

† That is, staked out and recorded.

The *Montaños* mine seems to have been opened at the junction of two larger and several minor veins. The principal opening is on the edge of a nose of the mountain which, stretching out to the south, forms a very steep declivity on all sides but one, and the western boundary of a deep ravine. The first noticeable vein here, dips about E. 35° N.—85°, and can be traced for some distance down the mountain side. The walls of this vein are, like those previously mentioned, ill-defined. At the main entrance the ore-bearing zone is very much enlarged, owing to an intersection of this with another vein, which is nearly flat. This great enlargement of the outcrops and the abundance of galena and "pay dirt" everywhere in sight, have combined to instigate a very complete exploitation of the mine, whence large quantities of lead and silver have been obtained.

On entering the mine, the eye is instantly arrested by the confusing appearance due to three larger, and numerous other smaller, strings and leaders which render it difficult to comprehend at the first glance their true relations to each other.

Openings of various magnitudes have been made on the flat vein at several points around its periphery, and at the point near the boundary line of the property which is given in the accompanying sketch. A good exposure of this vein gives a dip of W. 20° N.—15° to 20°. (See plan.)

A newer opening than that first mentioned was called the *Boca Nueva* by a miner. Here the dip in the flat vein is W. 30° N. It is thus seen that two principal veins dipping nearly at right angles to each other intersect at this point and increase very much the richness of the ore. The steep dipping-vein has not been very extensively explored, but the other has been worked throughout a great part of the area included between the boundary line above given and the sides of the steep hill. It may be due to this fact that the *Montaños* mine is known in the region as a low grade, while the *Pinitos* has the reputation of a high grade silver-lead mine; because, whatever be the reason, the highly inclined veins of this district, which belong to a different system of fissures and most probably to a different epoch, have been observed by the writer to carry, as a general rule, larger percentages of silver than the veins of low inclination.

In the mine, pillars are everywhere observable in which the ore, which is from eight inches to two feet in thickness (and exceptionally much larger), can be followed from one mouth to another. Specimens from a large number of exposures of this kind were care-

fully collected and averaged, and gave values of $10.32 of silver, and of $46.88 of lead per ton; making a total of $57.20 per ton.

The ore of the *Boca Neuva* above similarly sampled, gave $5.81 in silver and $44.27 lead, or a grand total of $50.08 per ton.

Most of this ore is in a ferruginous mass of impure carbonate of lime, but the richest of it is associated with a very white calcite which generally accompanies the latter as a superior or inferior layer; but is sometimes in it, and sometimes away from it altogether.

Allowing the thickness of the pay streak to be only 1 foot, at the assay value of the average from various places in the mine ($57.20) there is a value in sight from the flat vein alone, of $400,400. In this the vein of high inclination is not calculated at all.

The specific gravity of the average *Montaños* ore is about 4.52.

The Monclova District.

The Monclova district lies about eighty miles W.N.W. of Villaldama, and somewhat less from the town of Lampazos, which was my point of departure from the Mexican National R.R. The ride from this town is about twenty miles S.W, to Candela, at the foot of the picturesque mountain of that name. Thence through several *puertos* or passes one travels westward across the plain which separates the Sierra called *Madre* (like so many others), with its outlying peaks like *la. Rata*, etc., on the north from the Sierra de la Gloria on the south. Rounding the northern end of this latter one soon arrives at Monclova, a well-watered, quaint, and most interesting old Mexican town. It is distinguished alike for the green foliage and verdure which form a relief to the eye after days spent in these arid valleys, and for the exceptional picturesqueness of its old churches and streets, the latter unusually busy for the region.

La Paloma.

The iron-ore mine called thus is situated about seven miles southwest of the town of Monclova, the flourishing settlement on the stream of the same name in the northern part of the State of Coahuila, which has just been mentioned. The railroad from Eagle Pass is now finished to this town, and passes within two miles of the mine. The chain of mountains, on a spur of which this mine is situated, is called the *Cerro Mercado;* and the country rock, like that of the mines hitherto considered, is a massive limestone.

Monclova is, by uncorrected barometer, but 1937 feet above the sea,* and the mouth of the pit at *La Paloma* 2577 feet. It is, therefore, 640 feet above the general level of the plain, which extends to the south from Monclova, between this range and that of the Sierra de la Gloria, for about twenty-two miles to the Sierra San Márcos.

The mine is an immense deposit of iron ore and pyrites in a thick mass in limestone. The dip in the pit (which is ten varas deep) is N. 30° E. + 70°.

At the bottom, a layer of this pyrite, of about eighteen inches in thickness, covers a heavy mass of mixed hematite and magnetite.

The dip of the limestone of the south base of the foot-hills is about N. 30° E.—20°; but some large masses near the mine, which seemed to be in place, gave S. 40° W.—75°; so that the strikes of the limestone and of the ore nearly agree, and the latter has been probably deposited in one of the joints or cleavage planes of the latter, though it is possible that the spur itself may be anticlinal, and the iron ore deposit a true bed-vein. In either case there is the clearest evidence that the iron ore is an alteration product of the pyrite, but so complete has been the alteration that a few inches above the line of demarcation, between the sulphide and the oxide of iron, hardly a trace of the sulphur remains. The outcrop of this vein has been broken into large and small fragments, and it has been scattered over the side of the steep hill, which borders a very deep gulch or ravine leading directly down into the plain and to the railroad. It is difficult to estimate the amount of this sliding outcrop, but thousands of tons of a very fine quality of iron ore are here ready to be loaded and transported to the market, while the amount in the ground capable of easy mining is enormous.

It was very difficult to ascertain the thickness of this bed-vein, on account of the heavy débris and detached ore, which cover the surface from the mine-mouth to the bottom of the gulch; but, assuming a ridge of limestone which crops out about 25 feet below the pit, as one boundary, and the limestone exposed in the opening as another, there would be a thickness of 80 feet of ore and pyrite mixed with "horses" of the country rock.

* A note from Mr. E. A. Handy, engineer in charge of the Mexican National Construction Company, gives the correct level of Monclova as 1980 feet, but as the point is not specified, I have left the barometer-level as I obtained it.

In order to test the value of this ore severely, a sample was taken by the writer across the face exposed in the pit, inclusive of a horse of limestone there visible and some scattered masses of sandy material. It is needless to say that all these impurities would have been discarded by the roughest system of mining, and the average percentage of the iron would have been correspondingly raised, yet, even this sample gave 53.80 per cent. of metallic iron, a result about equal to the average of the product of certain James River ores.*

The following are the results of a chemical examination of the two classes of ore, *i.e.*, A, a large sample of the ore taken across the present exposed face in the pit; and B, a large sample of the float ore in the vicinity of the mine.

The complete analyses of these two samples (A 1 and B 1) were made by the writer's assistant, Mr. Richard D. Baker. Independent determinations of the more important constituents (A 2 and B 2) were made by his assistant, Mr. C. Hanford Henderson. Both samples were taken by the writer himself.

The column X contains Mr. Henderson's determinations of a sample of the ore furnished by Mr. W. A. Butcher.

The specific gravity of A 2 was 3.9.

	A.		B.		X.
	1 p. c.	2 p. c.	1 p. c.	2 p. c.	p. c.
Insoluble residue,	11.860	....	2.880	....	....
Ferrous oxide (FeO),	16.015	....	14.469	....	....
Iron sesquioxide (Fe_2O_3),	59.244	....	73.365	....	....
Alumina (Al_2O_3),	6.976	....	6.315	....	....
Lime (CaO),	1.320	....	1.580	....	....
Magnesia (MgO),	trace	....	trace	....	....
Sulphur (S),	3.726	4.510	1.555	1.504	0.010
Phosphoric oxide (P_2O_5),	trace	trace	none	none	0.107
Sum,	99.141		100.164		
Metallic iron,	53.93	53.86	62.60	61.71	61.56
Phosphorus,	trace	trace	none	none	.047
Silica,	....	10.04	....	2.88	6.14

It will be interesting to compare these results with the appended averages of the best mines of the Marquette and Menominee districts in Michigan.

* See The Ores of the Middle James River, by the undersigned. Read before the Institute, at the Virginia meeting, 1881. *Trans.*, vol. xi., p. 201.

This ore, as will be seen, is remarkably pure and rich, and suitable for the manufacture of steel. It would be of great value as a mixture with cold short ores, and would pay for a long and expensive transportation.

The following table will exhibit at a glance the comparative values of this ore; the Durango ore, collected by Mr. John Birkinbine, and analyzed by Mr. A. S. McCreath, chemist of the Second Geological Survey of Pennsylvania; the ores of the Middle James River, which were carefully studied by the writer in 1880–81; the celebrated Menominee and Marquette ores of Lake Superior separately; and finally, the average of all the Lake Superior ores taken together. The column of values, at the foot of the table, is calculated on the basis of nine cents per unit of iron, which is the price given by Mr. Francis Wister for foreign iron-ores at this date, January, 1884. It should be observed that high-class Bessemer ores are restricted to less than 0.05 of phosphorus, and those containing more than that are not received.

Pl. av. is the average of the two analyses, A 1 and B 1.

Pl. crop. is the average of the two analyses, B 1 and B 2.

D. 27. is the analysis of an average of twenty-seven samples of ore from near Durango, in the Cerro del Mercado,* taken by Mr. John Birkinbine.

D. 4. is the analysis of the average of four selected samples of the above.

J. is the average of eighty-two analyses for iron, seventy-two for phosphorus, and twenty-two for silica, of the ores of the Middle James River, Virginia.

Mnee. is the average of forty-eight determinations of iron, forty-five of phosphorus, and twenty-five of silica, of the ores of the Menominee iron range, Michigan.

Mqt. is the average of eight determinations of iron, eight of phosphorus, and eight of silica, of the Marquette region, Michigan.

S. is the average of fifty-six determinations of iron, fifty-three of phosphorus, and thirty-three of silica, of Menominee and Marquette iron ores of Lake Superior.

On the lower line is a calculation of the value of ores at the rate of nine cents per unit (omitting all those containing over 0.05 per cent. phosphorus).

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* It is perhaps needless to remark that the "Cerro del Mercado" of Mr. Birkinbine's report, is about 250 miles southwest of the Cerro Mercado spoken of here.

	P. c. Pl av.	P c. Pl. crop	P c. D 27	P. c D 4.*	P c. J.*	P c. Mnec	P c Mqt *	P c. S.
Metallic iron, . .	53.89	62.15	55.80	62 77	48.68	62 88	66.01	63.33
Phosphorus, . . .	trace	trace	1.328	0 288	0 07	0 023	0.063	0.0293
Sulphur, ...	4 12	1.530	0 085	. . .	. . .	. . .	. . .	. . .
Silica, ...	10.01	2.88	7.760	5.240	23 98	4.49	2.22	3.40
Value per ton, . .	4.84	5.55				5.66		5.70

In this connection the information contributed by the report of Mr. John Birkinbine, Secretary of the United States Association of Charcoal Iron Workers, is interesting. In the report, from which the extracts of analysis in the above table are taken (D 27 and D 4), Mr. Birkinbine says of the Durango iron ore deposit:

"A deposit which covers so great an area as 10,000,000 square feet, and yields an average of 55.8 per cent. metallic iron from samples containing considerable foreign matter, fairly representing the average of the ore, is unusual; and samples from an area of fully 7,000,000 square feet, which analyze nearly 63 per cent. of iron, demonstrate the value of the deposit. The only constituent of the ore which shows to a possible disadvantage is the phosphorus; this is not excessive,† and, by the application of the basic lining, could be used to produce Bessemer steel."

The writer cannot say positively how large an area is covered by the float ore of the La Paloma, which gave the analysis introduced into this report, but it is his belief that it will cover 7,000,000 square feet, while the total absence of phosphorus indicates that this ore is much more valuable than that which was the subject of Mr. Birkinbine's examination.

There is no industry in Mexico which promises fairer returns than that of the manufacture of iron from these rich Mexican ores, and on this subject I will quote again from Mr. Birkinbine's report‡ the fol-

* Ores thus marked contain above the limit of phosphorus previously allowed as the maximum in the purchase of foreign ores for Bessemer uses.

† This is for the 10,000,000 square feet; phosphorus 1 328 per cent.; for the 7,000,000 square feet 0.288 per cent.; and from the pig and bar iron from these ores 0.428 and 0.193 respectively. Mr. McCreath states that this result is lower than the average of our mill and forge irons, and the latter is "not excessive," in proof of which he gives analyses of standard English gun-tube irons four times worked.

‡ March 22d, 1882. These prices have altered somewhat, doubtless, since that date, but their relation to those of Monclova is probably unchanged.

lowing table of prices of iron articles in Durango and the United States, together with the duty per pound in cents for importing them.

Name of Article.	Durango Price per lb. Cents.	U. S Price per lb Cents	Duty per pound. Cents.
Nails, ...	25 to 31	3½	5½
Spikes, ...	25	3½	5½
Horseshoe-nails, ...	56	18 to 25	5½
Wagon-springs, ...	37	10	5½
Bar-iron, ...	13	3¼	2½
Sheet-iron, ...	20 to 24	3¼ to 6½	4½
Iron wire, ...	25 to 50	4 to 8	4½
Castings, ...	10 to 13	2½ to 4	1½
Window-gratings, ...	18	4 to 5	13
Wood-stove (oval 12x18x30 in height),	$55 each	$10 each	8 c. per lb.

The Durango prices are not likely to differ in important respects from those at Monclova.

Mr. Birkinbine confirms the opinion of all competent observers who have recently been in Mexico as to the great and increasing need of manufactured articles of iron in that country. This need will increase in arithmetical progression for many years to come. He alludes to the possibility of the additional industry of tin-plating being added to that of iron manufacture on account of the occurrence of tin deposits in Durango. He mentions the articles most in demand in Mexico in the near future, as iron and steel-rails, frogs, wire, bar, plate, and sheet; spikes, nails, tin-plate, and castings, and machinery for mines and factories.

He recommends the erection of a plant consisting of a blast furnace, a small rolling-mill, machine-shops, foundry and smithery, and estimates their cost at $250,000 to $300,000. In his opinion the manufacture of pig-iron will not cost more in Durango than in the United States, and "with ample capital and good management" he "cannot see a doubt of success attending the establishment of a modern iron industry at Durango." As the official representative of one of the most important iron associations in the world, his testimony is of great weight, and what he has said of Durango is equally true of Monclova.

RIOJAS.

This mine is situated in a mass of intrusive granite about four hours' walk southwestwardly from the *Paloma*, and not far from

the Iglesia peaks, which border the broad plain, which stretches out at right-angles to the Monclova-Castaño plain, and near to the limestone-granite contact.

The vein, which is stained green by copper-salts, and includes a narrow seam of felspathic gangue, is about two varas wide, and dips E. 10° S.—85°. The pit is about the usual depth of ten varas, but no lead or silver ore was apparent either on the lower face or on the sides, though at first it was thought that specks of galeniferous ore were present. The opening was made along the strike N. 10° E.

At a depth of five varas, or half the depth of the shaft, there was a small spot in the hanging, in which it was thought that ore occurred. It was a copper-stained gangue, containing small particles of hard, black material, with metallic lustre. The patch, in which the mineral occurred, was not continuous above or below, and was altogether 2 or 3 inches broad.

The above observations were made in the main pit or shaft, which is the second, reached by a southwestwardly route from Monclova. A rough line was run hence N. 10° E. over a sharp, short ridge intervening between this and the first shaft, encountered on the route, and it seemed to establish the fact that these two shafts were sunk in the same vein, as the direction agreed with the strike, and signs of the outcrops were observed between the two. The distance between them is about ± 1500 feet, but the second shaft has fallen in, and, beyond a tradition that the Spaniards once worked it, nothing could be ascertained concerning it by the writer. Its depth is also unknown.

Still further north, but not on the strike of the *Riojas* vein, on the opposite side of a narrow cañon, is a long, deep cut, running about S. 30° W. for sixty feet. It is thought that this opening is on the *Riojas* vein, but this fact could not be established by the rough means available in a short visit, nor was anything further ascertained about this working.

The same may be said of a shaft to the south of the first opening described, which, however, seemed entirely off the line of strike of the vein, though this too was indicated as an opening in the Riojas, but it was said that it had fallen shut, and it was not visited.

A small stream of water is found about a mile from the Riojas mine. The best route for the ore if mined in quantity would seem to be over the divide to the great transverse plain which separates the mountains in which the *Riojas* is situated (Cerro Mercado) from the Sierra de San Márcos.

The uncorrected barometer level of the mouth of the *Riojas* mine,

above the ocean, is 3077 feet, or 1097 feet above Monclova, but the summit of the divide or the head of the Las Animas Cañon, is 4027 feet, so that the transportation, if in this direction, would involve a minimum distance of nine miles to Monclova, and an ascent of 950 feet.

SAN RAFAEL

is situated on the north side of the Cañon del Real Viejo, in the Sierra San Márcos range, about nine Mexican leagues or twenty-three miles southwest of Monclova.

The metalliferous zone of which it forms a part, is also near a contact of limestone and granite, though wholly within the latter rock.

The road is from Monclova, nearly south to Castaño, a distance of eleven miles. From Castaño it deflects eastward through the fertile fortified Hacienda of Palo Blanco. Hence the trail is over the plain and into one of the cañons south by the spurs of this range. One of the valleys is called the Cañon de los Caballos, and this is the shorter route to the mine, but it is not chosen when camp is to be made, because its wide expanding wings concentrate the storm and rain winds, whereas the south wall of the Cañon del Real Viejo, immediately south of it, is a protection against the northers.

Castaño is 2462 above the sea by uncorrected barometer level, and Palo Blanco 2662, which would make the former 525 and the latter 725 feet above Monclova. The mouth of the Cañon del Real Viejo is 3155 feet above Palo Blanco, which is distant about nine miles. To this point, therefore, all the ordinary modes of transportation could be successfully applied. From here to the base of the steep ascent to the *San Rafael* mine is 400 feet and the distance about ten miles. At this point the steep ascent to the north begins over a granite spur which appears soft and friable, like a weathered gneiss. At the base of this hill flows a small stream, which is said never to run entirely dry. Notwithstanding its small volume it would be of great value to the prosperity of any works erected here, as the portions of the range on the divide into the Real Viejo Cañon are destitute of water, like all the districts in limestone in this part of Mexico observed by me.

As just stated, the rock of the north boundary of the cañon is pulverulent and friable like a rotten gneiss. Many loose fragments of feldspar are observed. Many granite and feldspar and small quartz veins cutting the side of the hill are passed, and besides these, a dyke of

syenite, south of the shaft, strikes N. 5° W., — vertical, and would intersect the *San Rafael* if continuous, near the deep shaft.

The first shaft passed on the vein is about 10 varas deep and is sunk on a whitish mass, striking N. 30° E., vertical or dipping slightly to the E. 30° S.

The deep shaft gives evidence of having been extensively wrought. The vein is two feet wide at the top or outcrop and exposes across its face bands of quartz and feldspar, of which the detached fragments frequently contain ore. At the surface the dip is E. 20° S.—85°. A short distance down the slope the vein changes to E. 40° S. —80°, and at a depth of 20 varas it changes to a vertical dip, widening also somewhat. Its strike is N. 35° E. and its breadth about one vara, or 33.38 inches.

The opening was in a very dangerous condition, and there are at present four victims of the culpable carelessness of somebody, who lie buried at the bottom of the shaft where they were crushed seven years ago. The slopes have been irregularly made, and have been left without timbering of any kind. In time the granite, which has been very much fractured, has partially detached large blocks from the sides and roof; and the whole excavation is thus lined to the base of the last shaft.

A very slight shock would bring down one or more of these and effectually seal the opening against all efforts to escape. The writer examined this mine to the depth of about 20 varas.

The vein matter is a weathered feldspathic granite which is said to be poor down to a level which by a singular coincidence corresponds with the present bottom of the mine. This statement cannot be now verified, but has not any reason that the writer could see to support it. Specimens taken by him from the surface outcroppings of the vein had an average specific gravity of 2.46, and on assaying were found to contain $15.48 in silver and no lead (as might have been anticipated from the low specific gravity).

There are altogether six shafts on this vein averaging 8 varas in depth and about 10 varas apart, but none of them were in a condition to examine, except the deep shaft above considered.

A narrow seam of very feldspathic granite lies on the hanging of this shaft. It is $\frac{3}{4}$ inch thick, and is said always to mark the surface of this wall in the deep, though it is also said to thicken very much there.

About six inches from the hanging, a vein of *guija* (gangue), is noticed to carry ore.

The mountain facing this ore and on the north side of the cañon, is a limestone mountain, as also that which faces it to the north across the cañon of the Caballos. Both these cañons are, therefore, depressions caused by contact of intrusive granite and limestone. The road up the Cañon de los Caballos is the shorter but much the rougher of the two. The ores, if free milling ores, could be treated with advantage near the mouth of the ravine, and the bullion transported through either of these cañons to the market.

In the cañon are numerous ruins of old works (some of Spanish origin), including one for the treatment of the ores which was only abandoned a few years ago.

This locality has all the elements of a region rich in mineral veins. That is to say, the presence of this great granite mass in the midst of the limestones, and the existence of the many dykes which have cut through it, have furnished conditions which are favorable to the deposition of metalliferous matter. But it is not necessary to speculate inductively on this subject. The depth to which this mine has been wrought; the many other mines in the neighborhood which were once wrought by the Spaniards; and more than all, the extensive mining enterprises being conducted in the Potrillo, just over the divide, and within a mile or two of this place, all point to it as one where the probabilities of mineral wealth are very strong.

In the table on the next page I have endeavored to condense as much as possible the scientific and economical data which have resulted from the examination of these ores. In this table, the first column comprises the samples so marked as to indicate whether collected by the writer or simply given to him and collected by some one else. Under the head of SILVER the values per ton are given, both at the rate at which silver was selling in January, 1884, and also on the less commendable but more usual calculation of the "coin value," or that value which is ascribed to silver in the coinage, on the supposition that the copper alloyed with it has no value and the silver alone is worth the denomination of the coin. The lead has been calculated in per cent. and afterwards at the ruling price at the same epoch. Finally, the sum of the two values is given in the next to the last column, and the specific gravities in the last column.

Some values have been suppressed for reasons connected with the business interests of the Company which desired this investigation to be made.

Mexican Ores, analyzed in the Laboratory of Dr. Persifor Frazer, of Philadelphia, by Mr. C. Hanford Henderson.

Ores marked with (*) were collected by Dr. Frazer. Ores marked with (†) were furnished by other persons.

	Silver per Ton.			Lead.			
	Ounces.	Value, $1.10 per oz.	Value, $1.29 per oz.	Per cent.	Value per ton, @ 4 35 cts.	Total Value per ton, 2000 lbs. Lead and Silver (1 29).	Sp. Gr.
* 1. Arroyo Mine. Average across heading, . .	trace		. . . .	6.59	$5 73	$5 73	3.20
* 2. Arroyo Mine. Pay dirt, selected by P. Roblez, .	15	$16 50	$19 35	21.31	18 54	37 89	
† 3. Arroyo Mine, ...	23	25 30	29 67	40.25	35 02	64 69	
† 4. Arroyo Mine, ...	33 5	36 85	43 22	43.14	37 53	80 75	
* 5. Minas Viejas. Red ore of *Buena Vista* opening,	2.5	2 75	3 23	9.2	8 00	11 23	3.31
* 6. Montaños Mine. Specimens from various faces,	8	8 80	10 32	53.89	46 88	57 20	4.52
* 7. Montaños Mine. Average, *Boca Nueva*, . .	4.5	4 95	5 81	50.88	44 27	50 08	
† 8. Montaños Mine, ...	2.5	2 75	3 23	47.95	41 72	44 95	
† 9. Montaños Mine, ...	2	2 20	2 58	57.25	49 81	52 39	
* 10. Pinitos. Average of main vein, . . .	24	26 40	30 96	21.9	19 05	50 01	3.90
* 11. Pinitos. South branch of south opening, . .	2	2 20	2 58	5.92	5 15	7 73	
* 12. Pinitos. Gangue mass in face of drift, . .	1	1 10	1 29	0	. . . .	1 29	
† 13. Pinitos. ["Panetious No. 2"], ...	45.6	50 16	58 82	31.24	27 18	86 00	
† 14. Pinitos. Ore from No. 2 opening, ...	330.2	363 22	425 9[illegible]	60.1	52 29	478 25	
† 15. Pinitos. ["Dirt out of Panetious main opening"],	849.8	934 78	1096 24	46.11	40 12	1136 36	
† 16. Pinitos. "Dirt," No. 1, ...	55.5	61 05	71 60	51.36	44 68	116 28	
† 17. Pinitos. "Coarse," No. 1, ...	53	·58 30	68 37	42.87	37 30	105 67	
† 18. Pinitos. "Fine," No. 1, ...	145.5	160 05	187 70	42 66	37 11	224 81	
† 19. Pinitos. "Uncobbed fragments," No. 2, . .	43.5	47 85	56 12	35.11	30 55	86 67	
* 20. Riojas Mine. Bottom of shaft, ...	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	3.24
* 21. Riojas Mine. From Mr. Day, ...	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	
* 22. Riojas Mine. From Mr. Hartz, ...	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	
† 23. Riojas Mine, ...	29	31 90	37 41	61.21	53 25	90 66	
† 24. Riojas Mine, ...	527	579 70	679 83	65.32	56 83	736 66	
* 25. San Rafael. 10 varas from surface, . . .	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	
* 26. San Rafael. Across outcrop, ...	12	13 20	15 48	. . . .	. . . .	15 48	2.46
* 27. San Rafael. 60 varas deep, ...	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .	
† 28. San Rafael. "Metal,"	75 2	82 72	97 00	trace	. . . .	97 00	
† 29. San Rafael. Main opening, ...	304.2	334 62	392 42	48 27	41 99	434 41	
† 30. San Rafael, ...	1	1 10	·1 29	38 74	33 70	34 99	

Mill Site near Monclova.*

An examination was made of a fine mill-site, two and a half miles southeast of the town of Monclova, known as the Campañas. The river Monclova, which flows through the town of that name, separates into several branches at the Campañas and reunites further down the stream. After following the stream up the current from Monclova, one soon passes into a valley bounded by low narrow ridges of conglomerate, containing pebbles of the carboniferous limestone of the Sierra de la Gloria and the Cerro Mercado. These hills separate more widely towards the head of the Campañas, and, finally, after sweeping around a flat and fertile meadow of five or six acres, run directly across the course of the stream, forming a waterfall and rapids of sixty-five feet.

A very rough experiment, made with a view of testing the volume of the portion of the stream which forms the falls on the Monclova side of the river, gave 21,000 gallons a minute.

This would furnish ample power for a stamp-mill, dressing-works, and compressed air for a blast furnace; and, if more power were necessary, about three times as much could be obtained by employing the whole stream instead of the portion of it which has been mentioned.

The situation has not escaped the observation of enterprising men in the past. A large cotton mill was erected here by an Englishman, and worked with profit for some time, until its final destruction by fire.

The cliff over which the stream plunges is the same conglomerate, of which the upper part is decomposed into earth and pebbles, the latter being rolled fragments of the limestone of the great ranges of the Sierras de la Gloria and San Márcos. A vein of highly ferruginous matter about 3 varas in thickness crosses the conglomerate, striking about S. 20° W.

FUEL.

A most important element of success in any undertaking to work the mines previously described, is the question of fuel.

At present the charcoal made from the Mesquite and other trees of the region, has sufficed to supply this demand; but in spite of the fact that some of this charcoal is quite compact and tenacious, it will soon cease to be available except in abnormally favored regions, because tree-growth is not a strong feature of this region, and most of

* See Plate 7.

the plants which replace it have not that woody fibre which is best suited to make good charcoal; and even in the opposite case it is hardly doubtful that good coke would be a better material.

In discussing the subject of fuels in the report quoted above, Mr. Birkinbine says of the Durango ore that it would not be advisable to construct an ironworks at that locality, dependent on mineral coal or coke for fuel, but that the railroads will soon establish a communication with coal deposits. Further on, he states the cost of charcoal (made from the Mesquit and Huysachic woods, either of which he adds makes a hard dense charcoal which possesses unusual calorific power) as 8 to 10 cents a bushel, which "could be much reduced if more modern practice was employed, and large quantities produced."

Without discussing the question with Mr. Birkinbine of what species of fuel will ultimately prove most advantageous to the Mexican iron industry, it may be remarked that his suggestions are well worthy of attention.

Monclova is about seventy miles southwest of the extensive coal fields opened up by Dr. H. B. Butcher.

The communication is by the Hermanos Pass, and there would probably be but little difficulty in running a narrow-gauge road by the Rio Salada, and through Progreso (provided no nearer coal-fields be opened), to connect the mines and Monclova, which is destined in any event to be a commercial and manufacturing centre of great importance.

In this connection the practice at the Pánuco smelter at Candela, is quite interesting. These furnaces have been conducted by Dr. Henry B. Butcher, and have been run on the coal which he first discovered near the river Sabinas (?) twenty miles north of Progreso.*

Dr. H. B. Butcher informs me that the reverberatory (Swansea) furnaces were capable of treating four charges of 1½ to 2 tons of the Pánuco copper ore in a day, and that to do this, required from 3 to 3½ tons of coal. The total amount of ore would thus be 6 to 8 tons, and the limestone mixed with it from 120 pounds to 200 pounds. In other words, from 12,120 pounds to 16,200 pounds of charge was treated by 6000 to 7000 pounds of coal, which shows very well for its duty on the large scale. An inspection of the residue left under the grate

* This locality is marked in the specimens of fossils which he was good enough to give me "Sabinas," though on his map the coal-mine occurs on a river marked "Rio Sa" which is seen to form a junction with a stream called the "Salada."

revealed numerous fragments of well-coked coal, which was coherent and well adapted to metallurgical operations.

. I selected some of the coal from the bins at the furnace, and had it analyzed in my laboratory by Mr. Henderson, with the following results:

Specific gravity of coal,	1.46
Hygroscopic moisture,	.54
Volatile combustible matter,	19.26
Fixed Carbon (Coke), by difference,	62.32
Ash (light grayish white),	17.88
Total,	100.00
Fuel ratio,	3 23

The following check analysis was subsequently made by Mr. Richard D. Baker of another fragment of the same piece of coal.

As the two analyses were fragments and not from an *averaged* lot, the differences are unimportant.

The lesser percentage of volatile combustible matter in the following analysis may be due to changes which had taken place in the coal itself during the two weeks of its exposure in the laboratory intervening between the two analyses:

Hygroscopic moisture,	.51	
Volatile combustible matter,	18.76	
Fixed Carbon (Coke) by difference,	65.35	
Ash (light grayish white),	15.38	
	100 00	
Sulphur,		0.317
Phosphorus,		trace.
Fuel ratio,	3.48	

It may be interesting to compare this result with that obtained from a specimen of coal from the Carazal, which was furnished by Mr. W. A. Butcher, and analyzed by Mr. Henderson.

Specific gravity of coal,	1.39
Hygroscopic moisture,	0.58
Volatile combustible matter,	16.24
Fixed Carbon (Coke), by difference,	64.48
Ash (grayish white),	18.70
Total,	100.00
Fuel ratio,	3.97

The fuel ratios, or the ratio between the solid and volatile hydrocarbons, are 3.23, 3.48, and 3.97, which place them well within those of bituminous coals, *i.e.*, those having a fuel ratio of from 5 to 0.

It will be understood by all those familiar with coals, that the large percentage of ash in the above analyses is a variable factor which is almost certain to be very much reduced when the mines get to producing on the large scale. The fuel ratio was a means suggested by the author, to ascertain the true relationships of the coal independent of this fortuitous factor.*

It is, of course, of the greatest importance, in the great development which Mexico is almost certain to undergo in the next few years, that fuel, the most important adjunct to such development, should be obtainable from her own domain, and near the scenes of the operations which foreign capital is about to commence.

List of Levels obtained from Mr. E. A. Handy, Engineer in charge "Mexican National R.R.," Saltillo, Mexico.

	Feet above ocean level
Laredo, Texas,	**438**
Lampazos, Mexico,	**1032**
Villaldama, "	**1412**
Monterey, "	**1790**
Garcia, "	**2334**
Saltillo, "	**5253**
Puerta de los Carneros, Mexico,	**6916**
Matehuala, "	**5360**
Solis, "	**6138**
Monclova, "	**1980**
Monclova,† "	**1948.85**
Castaño,† "	**2431.14**

The Corrected Barometer Levels based upon the above data. Taken by the writer in Mfxico, November and December, 1883.

	FEET ABOVE SEA		FEET ABOVE SEA
Laredo (Texas),	**438**	Bridge over Salado,	558
Bridge over Rio Grande (?),	518	Mojino (station M. N. R.R.),	733
Nuevo Laredo, Mexico,	568	**Lampazos,**	**1032**
First cut west on railroad,	633	Golondrina (station N. M. R.R.),	1407

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* See *Transactions of Am. Inst. of M. E.*, vol. vi., p. 430, and publications of the 2d Geol. Surv. of Pa., vol. M., p. 128.

† Data obtained from the Mexican International R.R.

	FEET ABOVE SEA
Guadalupe (station N. M. R.R.),	1462
Pass through foot-hills west,	1637
Second Mescal Ranche,	1812
Piedras Pintas,	1987
Near foot of Yguana Range,	2612
Cedar Tree (at Candela Fork),	3212
Later,	3837
10 minutes later,	4152
15 minutes later (summit),	4462
8 minutes later (commencement of descent),	4462
14 minutes later (foot of steep descent),	4212
Jacal M. Viej (15 minutes later)*	4062
Boca Negra,	4337
Mouth of *Buena Vista* drift,	3897
Doctor,	3797
Guadalupe Mine,	3517
Boundary of *Arroyo* (*S. of Claim*),	3497
Mouth of *Arroyo* Mine,	3342
Near bound. of *A*, head of gulch,	3437
Villaldama Station,	**1412**
Villaldama (Botello's),	1372
In Villaldama Valley,	1747
Jacal d. San Isidro del Potrero,	1822
Mouth of Potrero Cañon,	1917
100 yards east of the following:	2697
San Antonio,	2722
Jacal de Don Tomas Gonzalez Villareal,	2747
45 minutes on road to *Pinitos*,	3642
Estacado (halting place),	3742
15 minutes from above,	4492
Encino Gordo (second halting place),	4607
Pinitos main opening,	5317
Botello's jacal,	6067
1st halt on road to *Montaños*,	6267
2d halt on road to *Montaños*,	6317
Water hole nearest jacal,	6367
Minor summit on range (road to *Montaños*),	6387
Vein, outcrop on route,	6342
Summit on route to *Montaños*,	6567
Principal mouth of *Montaños*,	6017
Summit, 3 hours later, 12.45 P.M.,	6567
25 minutes later, Botello's jacal, 1.10 P.M.,	6067
Hacienda San Anton. (foot of field),	2672
Lampazos town (Vasquez's shop),	1092
El Paso Creek (road to Candela),	1132
Candela (Dr. H. M. Butcher's house),	1012
Candela (copper furnaces),	1612
Entrance to Puerto,	1767
Middle of Puerto,	1882

	FEET ABOVE SEA
Ojos Calientes,	1872
Puerto San Antonio,	2252
Road crossing ridge east of *Pánuco*,	2752
House at *Pánuco* Mine,	3742
Mouth of Graham Level,	4017
Tree near gold mine, in bed of brook,	3927
Gold Mine (of W. A Butcher),	3977
Summit between Gold Mine and *Pánuco*,	4377
Road from *Pánuco* Mine, at second arroyo,	3077
Intersection with main road to Monclova,	2217
Ranche del Salitrillo,	1937
Hacienda de la Mota,	1937
Carizo Lejos,	1727
Hacienda de El Oro,	1877
San José,	1917
Jim. Denning's (Monclova),	1937
Monclova (Point unknown R.R. datum),	**1980**
Monclova,*	**1948.85**
Head of Campañas,	2025
Bottom of hill,	1972
Foot-hills, 5 miles southwest of Monclova,	2427
Opening of *La Paloma*,	2577
Ridge between cut and *Riojas*,	3627
Summit of Divide Las Animas Cañon,	4027
Water line Las Animas Cañon,	3427
Iron outcrops, Trail to *Riojas*,	3252
Mouth of *Riojas* (second shaft),	3077
Dump pile (first shaft *Riojas*),	3027
Road to Saltillo, opposite iron mine,	2187
Castaño,	2462
Castaño,*	**2431.14**
Palo Blanco (Coahuila),	2662
Camp. Cañon del Real Viejo,	3337
Water line below *San Rafael*,	3737
Mouth of first shaft *San Rafael*,	4437
Mouth of principal shaft *San Rafael*,	4512
Another point (foot of steep hill),	3787
Camp, near above,	1927
San Ramon,	1952
Highest point opposite Sierra Colorada,	1902
Dinner Camp,	1842
Bustamante Station,	1532
Palo Blanco Station,	1887
Salinas Station,	1547
Monterey Station,	**1790**
Monterey hotel,	1465

* Data obtained from the Mexican International R.R.

Amidst many conflicting data, unavoidable in a case like the present, where a large number of observations extending over a long time were made on a single aneroid barometer without even the check which simultaneous readings of a stationary instrument would have supplied, the height of Guadalupe station was assumed as 430 feet above Lampazos station, this being the mean of two sets of readings taken at intervals of two hours between the stations. This makes Guadalupe station 1462 feet above ocean level, and all the altitudes in the Villaldama district are calculated on this basis. The altitudes obtained in the Monclova district, and in the region between it and Lampazos, are calculated directly from the datum of Lampazos station. The isolated datum for Monclova obtained from Mr. Handy could not be used because the exact spot is not specified.

THE TORSION-BALANCE.

BY ALFRED SPRINGER, PH.D., CINCINNATI, O.

CHEMISTS, physicists and others, whose occupations necessitate the use of fine scales, have heretofore regretted their inability to obtain any which would remain uniformly accurate.

The difference between the theoretical and the actual results obtained in the ordinary balance (provided the pivot-distances are exact) is mainly due to the frictional resistance between the knife-edges and their bearings. This frictional resistance, although reduced to a minimum in the finest scales when new, constantly increases, thereby decreasing the sensitiveness proportionately.

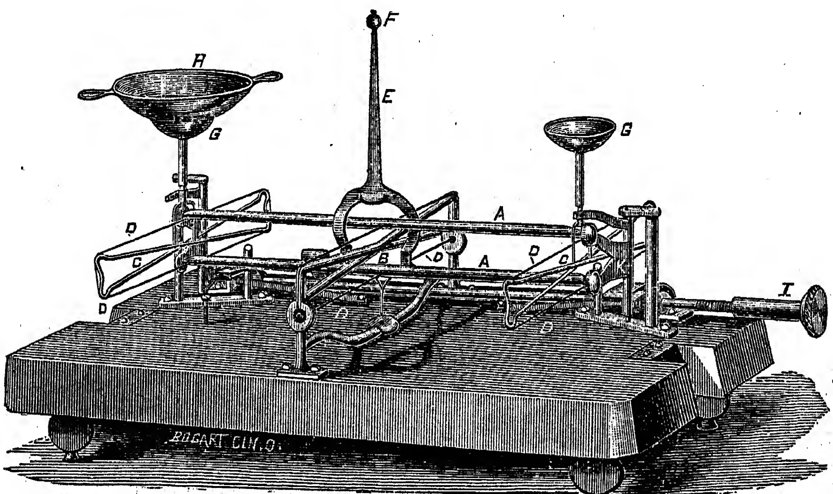
When examined under the microscope, neither the surface of the knife-edge nor that of its bearings ever appears perfectly smooth. Soft knife-edges are easily blunted, whereas hard ones are brittle and liable to crumble under the effects of over-load or shock.

Prof. Frederick A. Roeder for many years attempted to discover some means by which the knife-edge could be replaced with some device free from the above-mentioned objections. His experiments convinced him that a torsion-joint was best suited for that purpose. After he had communicated his conclusion to me, we jointly developed the system to its present form. A torsion-wire had been used for the centre of rotation, prior to Prof. Roeder's invention, but it was found impossible to replace the terminal knife-edges with torsion-joints.

The use of a torsion-joint introduces a new element opposed to sensitiveness, namely: that of resistance to molecular displacement.

In the scales manufactured by us, according to the size, thin wires of gold or bands or rods of an elastic material are strongly tensioned over suitable frames (which themselves are thereby strengthened by being equally pressed on all sides).

The centre frame *B*, being attached to the base of the scales, is an immovable one. On the upper and lower wire *D* of this frame a compound parallel beam *A*, *A*, is firmly attached. The ends of



A. A. Parallel compound beam. *B.* Immovable centre frame, carrying index and beam. *C. C.* Movable frames carrying the pans. *D. D. D.* Stretched gold wires over the frames, acting as central and terminal pivots. *E.* Index. *F.* Weight for the purpose of elevating the centre of gravity. *G. G.* Cups for pans. *H. H.* Pans. *I.* Arrest. *K. K.* Support to receive the weight of the scale when not in use.

the beams are similarly attached to the wires of the movable cross-pieces *C*, *C*. The purpose of the outer cross-pieces which carry the support for the pans, is to allow them to descend in a vertical direction, thus keeping exact fulcrum-distances.

Every part of the system being firmly soldered, the whole construction is in reality but a single piece.

The resistance to molecular displacement is augmented by the tension at which the wires are held, and increases with the angle of displacement. This resistance to torsion is many times greater than the frictional resistance between the knife-edge and its

bearings, but differs from the latter in this: that it does not vary with different loads; whereas the friction in the knife-edge increases with the load placed on the pans.

Now if this torsional resistance be compensated in some suitable manner, it is perfectly evident that it will play no further rolə in the working of the scales. This nullification of torsional resistance is effected in a peculiar manner which we have found to be perfect for any arc of oscillation used in balances.

As a compensation to torsional resistance, we make use of a "poise" *F*, above the centre of rotation, which has no effect upon the twisting of the wire as long as in the centre, but according to the laws of gravity has an increasing effect in proportion as it moves from its neutral position. This increasing force in oscillation exactly counterbalances the increasing resistance to molecular displacement, thus effecting an absolute nullification of the original torsional resistance in the wires, when oscillating. The scales are now free, not only from torsional resistance, but are absolutely frictionless.

For many purposes it is desirable to have less sensitive scales. When this is the case, the poise is simply lowered, until the required sensitiveness is obtained.

We have been asked frequently, whether the twisting of the wires does not tend to break them. We need only answer, that a careful observation will show that the wires are long and the arc of oscillation comparatively small; furthermore, every molecule partaking in the motion, no part of the wire undergoes much torsion. In fact, it is barely visible. Thus much for the smaller scales.

It will be readily understood that by moving one of the outer cross-pieces towards the centre one, and the other away from it, we obtain the common steel-yard with its ends of unequal length; that is, a single multiplying lever, in which the knife-edges are replaced with torsion-joints. Furthermore, if the long end of this lever be attached by a similar cross-piece to the short end of another such lever, we get the effect of multiplying levers as used in platform and other large scales, but with this great difference: that the multiplication of the torsion-joints in contradistinction to the knife-edges does not increase the error due to friction.

All the levers, like the simple scale, act as one piece; and the poise can be placed over every centre of rotation, or, if convenient, over a single one. We prefer to place it over the last one in the system, thus decreasing its size proportionately to the multiplication of the levers.

Both large and small scales constructed on this system are extremely sensitive and durable.

Discussion.

[Several members asked and received information, illustrated upon the blackboard, as to the details of construction of the torsion-balance.]

President Hunt: How large a scale have you actually constructed on this principle?

Dr. Springer: The first scale we constructed was an analytical balance, which was used at the Cincinnati University. Then we made a larger one, a grocery-balance. The last was a thousand-pound balance. We have tried to weigh letters on it, to determine the amount of postage required, and it does this with the greatest of ease. And there is no doubt that any size of bar can be used provided the torsional resistance is overcome.

Arthur V. Abbott, New York City: I had the pleasure of seeing one or two of these scales in New York a few weeks ago, and while I did not have an opportunity to give them the careful examination that I should have liked to give, yet they struck me as being exceedingly ingenious and useful contrivances. I would ask Dr. Springer whether he has made any experiments to determine exactly what the absolute sensitiveness of the scale is? I suppose, even in the very best mechanical contrivances, there is some little loss. I think that even in the famous Emery scale, Mr. Emery will admit, and does admit, that there is a slight loss. Although it is so very slight in comparison with the immense weights dealt with at the Watertown Arsenal, that it is practically inappreciable, yet there is a loss. My question would be this: Suppose we place on one of the pans a weight, for example, of one hundred pounds, now what is the smallest quantity of additional weight that will give a perceptible motion at the end of the beam?

Dr. Springer: It depends altogether on the number of transmissions. I do not think there is such a thing as any weight not having some action. The weight may be so small that the action may be imperceptible on the scale as we construct it for ordinary uses; but not if it is made for scientific purposes. If desired, we could put in a system of leverage, for which you could not find a weight so small that it would not show on some one or other of the levers. Of course, we are not making the scales as sensitive as that. The large scales we do not want to make so sensitive. There

is an objection to it. For instance, if a grocer's scales indicated a grain too much, or a grain too little, he would never stop weighing. But in analytical scales, or for gas-analyses, there is almost no end to sensitiveness; you want the end as sensitive as possible. But the first analytical balance did not have the requisite sensitiveness. With 150 grammes on either side the scale was sensitive to $\frac{1}{10}$ milligramme. Then it was not the perfected instrument that it is now. I dare say it is in its infancy at present. We have been working empirically to a certain extent. Our new balances will show $\frac{1}{100}$ milligramme when loaded to 500 grammes.

N. W. Perry, Cincinnati, Ohio: Did it ever occur to you, where extreme accuracy and fine weighing are desired, to have an electrical register? The difference in conductivity of these wires in different degrees of torsion, might not that give a good register for the minute variations?

Dr. Springer: We have made no attempts whatsoever in that line, and of course I cannot say what the effectiveness of such an arrangement would be.

F. W. Gordon, Pittsburgh, Pa.: I would ask Dr. Springer if he can give some opinion with regard to the liability to set by this torsion. That is to say, such a set as would be insignificant in ordinary mechanical appliances, but, in balances, would raise a question for very grave consideration. Have any experiments of value been made to determine that question?

Dr. Springer: We have taken that very carefully into consideration. The scale that we use up to 150 pounds, will not set with less than 1300 pounds, so that there is no possibility of an injurious set being caused by such small weights as 150 pounds and below. Our drug-scale will not set with less than a pound and a half, and the highest amount to be weighed on it is one ounce.

Mr. Kent: Are there any of these scales on exhibition?

Dr. Springer: For a week we have been 22 feet under water, and are 4 feet under now; but the scales are there, and I shall be glad to show them as well as I can to anybody who will risk the visit.

TAMPING DRILL-HOLES WITH PLASTER OF PARIS.

BY FRANK FIRMSTONE, EASTON, PA.

In the summer of 1881 we were forced to break up and remove the large mass of iron which had accumulated under No. 2 furnace at Glendon, in order to prepare the foundations of the new furnace which has taken its place.

We used "Atlas" powder, drilling the holes with a pair of Rand drills. These worked very well when the iron was at all uniform in hardness; but this was not often the case; and it frequently happened that the holes were hopelessly blocked when but little over a foot deep. Good tamping became, therefore very important.

The common method of tamping is certainly very dangerous when there is a percussion cap in the hole, and has, no doubt, caused many of the accidents attributed directly to high explosives. We found an excellent and safe method by using plaster of Paris, mixed to the proper consistency and poured into the holes as soon as they were loaded. Clean dry sand was mixed with the plaster to reduce the quantity needed.

With proper attention the tamping would set in a few minutes, and little or no more time was required than for tamping in the ordinary way.

We used a "magneto" machine (Laflin and Rand) to fire the holes; and an additional advantage in the plan was that any risk of cutting the exploder-wires in tamping was avoided.

We found it worth while to load holes not over 13 inches deep in a block 3 or 4 feet thick, since the bottom of the hole was enlarged by each shot so that the next time it could be loaded more heavily, and three or four shots in this way often did as much good as a new hole twice the depth, to drill which might have taken ten or twelve hours.

The rise in temperature when boiled plaster solidifies is not sufficient to ignite the exploders, as we found by repeated trials before using it in a loaded hole.

Discussion.

S. Whinery, Meridian, Miss.: During the summer of 1878, while engaged on the improvement of the Tennessee River at Muscle Shoals, Ala., under Major W. R. King, U. S. Engineers, I had occasion to blast a large amount of limestone rock from the channel of the river. The surface of this rock was from 1 to 3 feet below the surface of the water, and the drill holes were from 1 to 3 feet deep. The depth of water not being sufficient to make water-tamping entirely satisfactory, I experimented with several methods and substances for tamping under water. Among these, plaster of Paris was pretty thoroughly tried. When the charge of dynamite, with the platinum fuse, was in place at the bottom of the drill-hole, plaster of Paris, mixed quickly with sufficient water to make a rather thin mortar, was run into the drill-hole by means of a funnel and tin tube, the lower end of which was placed directly over the top of the drill-hole. The charge was allowed to stand twenty to thirty minutes for the plaster to set, when it was fired in the usual way by a dynamo-machine. This tamping gave very satisfactory results; but it was found difficult to have the plaster used properly and intelligently by the class of laborers employed, and the plaster would adhere and harden on the inside of the tube so as to fill and obstruct it in a short time. The advantage gained by this close and hard tamping, over the water-tamping, was not found to be sufficient to justify its use under the disadvantages named above, and it was discontinued. Where several hundred holes were to be drilled, charged, and fired each day, in sets of from fifteen to twenty each, and any delay in charging and firing seriously delayed the whole work, the saving of time, when the charge was simply sunk to the bottom of the hole, the wires connected, and the charge fired, was more than enough to compensate for the defective water-tamping.

Dr. R. W. Raymond, N. Y. City: I would call attention in this connection to the fact that, although the rise in temperature in plaster of Paris be not sufficient to explode any of our highest explosives, there is an element of danger perhaps not peculiar to the use of this substance; and yet, in proportion as it is a perfect tamping, in that proportion this element of danger is present. It is not safe to leave any of the high explosives (at least those which are compounds of nitroglycerin), after tamping for any considerable period of time, in such a confined position. A rise in temperature, which may not be enough of itself to cause explosion within a rea-

sonable period, is often enough to set a generation of gas going which will bring the pressure which *will* cause explosion. The thing to be done after tamping is to fire at once. My attention was called to this in the early days of the use of a nitroglycerin powder, on the Pacific coast. I think the case is mentioned in my first report (1869) as United States Mining Commissioner. As I recollect it, a hole had been tamped in the mine just about the time to go to dinner, and the men having gone to dinner leaving the hole with the exploder in it, but not lighted. It went off during their absence of itself, injuring nobody, but surprising them a good deal. They had the idea that dynamite was as safe as brown sugar; and among the miners the belief was that, in order to be safe, one had only to be careless with it, and leave it lying around loose. There was some truth in that maxim; but when you come to bottle it up, to pack it in a drill hole, and put tamping on top of it, then the elements of danger are present, and it is simply wise to fire it as soon as you can.

At the same mine, where I examined it with some curiosity, they had a box of cartridges, which they had brought and unloaded at the mouth of the tunnel leading into the mine, and to which the men went and fished out a cartridge as they wanted it. This box lay for some hours, the first day after its arrival, under the rays of a Californian sun. Well, all that happened was, that slowly the lid of that box rose right up. Without question there was a generation of gases going on at the comparatively low temperature caused inside a wooden box by the sun outside—a generation of gases—which lifted the lid and relieved the pressure, so that there was no explosion. But rigid tamping of a drill-hole would make trouble, I think, if it should be abandoned too long.

WILLIAM KENT, Jersey City, N. J.: I would suggest that, just before the tamping with plaster of Paris, some compressible substance be inserted, with the double object of preventing the conduction of heat and of making a compressible cushion, against which the gases could work, instead of confining them in a solid, close receptacle.

DR. RAYMOND: I am inclined to think that that expedient would rather weaken the effect of the high explosive in particular cases, like the one cited in this paper, when it is designed to burst asunder salamanders of iron. In that case I suppose that any compressible substance making a cushion would enable the charge to lift more and lose tearing power, because there would be a yielding at the instant of the first impulse, before it came to act directly upon the

rigid inclosure. I have no doubt that such a cushion would have the desired effect where tearing was not so much required as lifting, assimilating the effect of the explosion to that of gunpowder. I have no doubt that a safety-pad would be effective in counteracting the dangerous results of the generation of gases, and perhaps even increasing the force of powder; but at the same time I doubt whether it would do as good work in actually shattering solid rock.

WILLIAM KENT: The space occupied by the gases generated before the explosion is so small (being but a few cubic inches to several thousand times as much), compared with the whole volume of the gases after the explosion, that I think the effect in lessening the force of the explosion would be imperceptible.

W. S. AYERS, Allamuchy, N. J.: I have found in limestone that a cushion did affect the tearing power of the powder; that the explosion did not shatter the stone as thoroughly as it did when the cushion was not used.

THE IRIDIUM INDUSTRY.

BY WM. L. DUDLEY, CINCINNATI, O.

IT is my desire to call attention to a new industry which was started about four years ago, through the discovery by Mr. John Holland, a resident of this city, of the methods employed in working the metal iridium. This metal has been known since the year 1803, having been discovered by Smithson Tennant while investigating the metallic residue which remained when platinum ores were dissolved in aqua regia. The metal is classed among the rare metals, as it is not found in large quantities, although it is quite widely distributed geographically. It is found in California, Oregon, Russia, East India, Borneo, South America, Canada, Australia, and in certain parts of France, Germany, and Spain. The principal sources of supply of the metal are Russia and California; it is nearly always found with either platinum or gold, is extracted from those ores as a by-product, and is always found in small grains or fine powder, the largest pieces being about the size of a grain of rice. In nature it is generally alloyed with other metals, and the two metals with which it is most commonly alloyed are platinum and osmium; the platinum alloy is called platin-iridium, and the osmium alloy osmiridium, or iridosmine. The grains of platin-iridium are

sometimes found as small cubes with rounded edges, while the iridosmine usually exists in the form of flat irregular grains and occasionally as hexagonal prisms. The supply of metal which is derived from Russia is generally obtained from the platinum mines which are situated in the Ural Mountains; while in California it is found principally in the placer gold-washings. The ores of iridium are a source of great annoyance when mixed with gold-dust on account of its specific gravity, which is about 19.3, being nearly the same as that of gold. Consequently, it is impossible to separate the gold from the iridium by the process of washing; the separation may, however, be made either by the amalgamation of the gold (as neither iridium nor its ores combine with mercury), or by dissolving out the gold in aqua regia.

In the mints these metals are frequently separated by melting the gold-dust and allowing the molten mass to remain in the crucible for some time, during which the iridium slowly settles to the bottom, as it does not alloy with the gold under such circumstances. The gold is then poured off from the top, and the dregs in the bottom of the crucible are found to contain the greater quantity of the iridium. The gold contained in the dregs is then dissolved and the iridium remains in the residue.

In Russia it is contrary to the law to possess or deal in iridium ore, and, consequently, the government takes possession of all the ore which is mined or extracted from the platinum ores in that country, and it is stored in the vaults of the Royal Mint. The reason for the law is, that some years ago the Russian government found that speculators in gold-dust would sometimes add iridium to it (which often escaped detection by the officials of the mint), for the purpose of increasing its weight. On attempting to work this gold they found the fine particles of iridium distributed through the ingots; on rolling the ingots into sheets, these individual grains or particles produced indentations in their steel rolls; and in striking out the coins the dies were marred and defaced, thus causing considerable loss to the government. In order to prevent this species of fraud, the government passed a law prohibiting persons from handling the metal in any way and compelling its immediate surrender.

For a number of years experimenters have endeavored to melt the iridosmine or iridium in order to utilize it in the arts for such purposes as could with advantage employ a metal of its wonderful properties; but until lately success has been only partial.

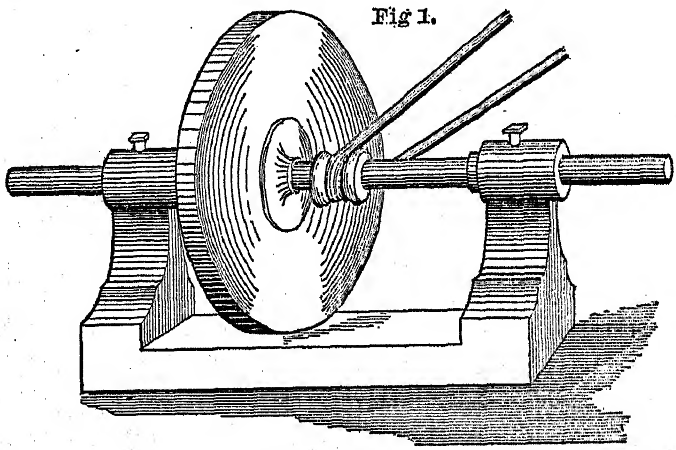
I may here briefly describe the properties of the metal itself. Iridium possesses a white lustre, resembling that of steel; its hardness is about equal to that of the ruby; in the cold it is quite brittle, but at a white heat it is somewhat malleable. It is one of the heaviest of metals, having a specific gravity of 22.38. When heated in the air to a red heat the metal is very slowly oxidized; but upon raising the temperature to about 1000 C., it parts with its oxygen, and hence at a high heat (above 1000 C.), it is not oxidized. It is insoluble in all single acids, but is very slightly soluble in aqua regia after being heated in the state of fine powder for many hours. In a massive state, however, aqua regia does not attack it.

In attempting to fuse iridium heretofore, it has been found by experimenters that the best results that could be obtained were by means of the oxy-hydrogen or electric furnaces, but that with either of these means of fusion they could only work a very small quantity of the metal at a time, and obtain a globule of very small size. Previous to the present time iridium has had substantially but one use (with the exception of alloying with platinum), viz., for pointing gold pens. The iridium point is commonly called "diamond point" upon a gold pen, and it consists simply of a small grain of iridosmine which has been selected for the purpose, and soldered to the tip of the pen. These points are selected by first removing from the ore, by means of a magnet, the magnetic oxide of iron which always accompanies it, and then dissolving out, by means of acids, the other impurities which may be present; the ore is then washed with water, dried and sifted in order to remove the fine dust, and the sifted ore is then ready for the selection of points. This is done by an operator, who rolls the grains of iridium around with a needle point, examining them under a magnifying glass, and selecting those which are solid, compact, and of the proper size and shape. These points are usually selected in three grades, small, medium, and large, depending upon the size of the pen for which they are intended to be used. The grain of iridium having been soldered on to the end of the pen, it is sawed in two (which makes the two nibs of the pen), and ground up in the proper shape.

About four years ago Mr. John Holland, the well-known gold pen manufacturer, found it necessary to have pieces of iridium larger than those generally found in nature for the purpose of making points for the Mackinnon stylographic pen. After many experiments he found that by heating the ore in a Hessian crucible to a white heat and adding to it phosphorus, and continuing the heating

for a few minutes, he could obtain a perfect fusion of the metal, which could be poured out and cast into almost any desired shape. This material was found on physical examination to be about as hard as the natural grains of iridium; and in fact seemed to have all the properties of the metal itself. On chemical analysis it was found that the metal fused with phosphorus contained, according to two determinations, 7.52 per cent. and 7.74 per cent. of phosphorus. At this stage of the discovery we became acquainted with it, and began experiments with the intention of putting the product to some practical use in the arts. It was found that the presence of phosphorus rendered the metal quite readily fusible at a white heat, but this, of course, was an obstacle in the way of its use for electrical purposes. Desiring, therefore, to remove the phosphorus, we found by experi-

Fig 1.



menting that by heating the metal in a bed of lime the phosphorus could be completely removed. In this operation, the metal is first heated in an ordinary furnace at a white heat, and finally, after no more phosphorus makes its appearance, it is removed and placed in an electric furnace with a lime crucible and there heated until the last traces of phosphorus are removed; the metal which then remains will resist as much heat without fusion as the native metal.

In mechanical applications, where the metal is not subject to great heat, it is melted with phosphorus and cast into the shape desired, and then ground or worked as the application may require. The first application to which it was put was for the manufacture of the Mackinnon pen-points. For this purpose, the metal, after being fused, is removed from the furnace and poured between two slabs of

iron, which are kept apart the desired distance so as to make a sheet of iridium of the thickness required. The metal is poured, as I have said, between these plates, and the plates are brought suddenly together, on the plan of a closed ingot with a hinge, so that as the metal cools it is subjected to pressure which closes the pores and makes a very compact casting. The slabs for the Mackinnon pen-points are about one-thirty-second of an inch in thickness, and are broken up into small irregular pieces which are soldered on a strip of brass and ground down to a flat surface by means of a copper-

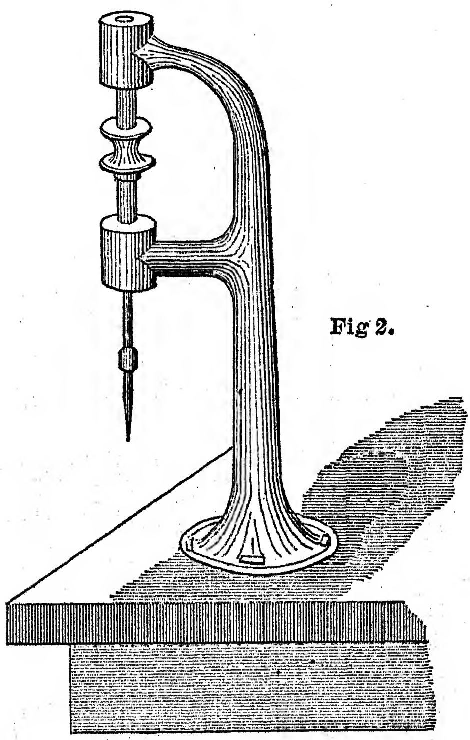
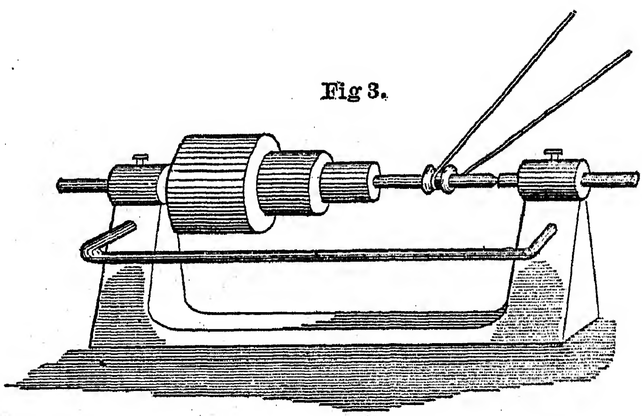


Fig 2.

lap. The copper-lap (Fig. 1) consists of a plate of copper, about one-half inch in thickness and eight inches in diameter, fixed on a spindle which is made to revolve from eight hundred to a thousand revolutions per minute; the copper of which the lap is composed is wrought copper, well annealed, and consequently very soft. In order to grind with it, corundum or diamond-dust is mixed with oil and applied to the flat surface of the lap by means of a flat steel instrument, upon which pressure is applied in order to force the corundum or diamond-dust into the copper, thereby making a cutting

surface. The iridium to be ground is held against this sharp surface of the lap, and the corundum or diamond-dust gradually cuts the metal away. As the cutting material wears from the copper-lap, another application of the corundum and diamond-dust is made by means of the steel instrument as described; this operation is continued until the grinding is complete. After the slabs are ground to a surface they are then drilled. In the drilling operation, the iridium is first countersunk by means of a diamond drill, consisting of an upright spindle suitably fixed in a frame so as to revolve freely; the bottom of the spindle holds a small rod of brass, to the lower end of which is set a white diamond-splint. This drill is made to revolve about nine hundred revolutions per minute. The iridium is held up against the diamond with a light pressure, and the diamond gradually makes a conical hole or countersink. After countersinking the iridium, it is finally pierced by means of a copper drill (Fig. 2), which consists of a piece of soft copper wire, which is filed down to a point and set in a drill similar to that in which the diamond is placed, but this drill makes about thirty-five hundred revolutions per minute. Corundum or diamond-dust and oil is put into the countersink opening in the iridium, and then it is held up against the piece of revolving copper. The diamond-dust or corundum, imbedding itself in the copper, acts as a cutting surface, and finally accomplishes the drilling of the hole. The holes having been drilled in the pieces of iridium which were soldered to the brass, the brass is finally dissolved from the iridium by means of nitric acid; and then we have irregular-shaped pieces of iridium, pierced with holes. These pieces of iridium are then soldered in proper position to the

Fig 3.



end of the Mackinnon pen, fitting into the opening of which there is a valve consisting of an iridium-pointed wire. The iridium is then ground to the proper shape on the outside by means of a copper-lap, as shown in Fig. 3, consisting of three or more copper cylinders on a common spindle, making about three thousand revolutions per minute.

The operation of sawing iridium is carried on by means of a copper disk (Fig. 4), from four to eight inches in diameter, made of soft thin sheet-copper, held between two clamps, placed on a spindle revolving at the rate of about twenty-five hundred revolutions per minute. This sheet of copper revolves in a box which contains

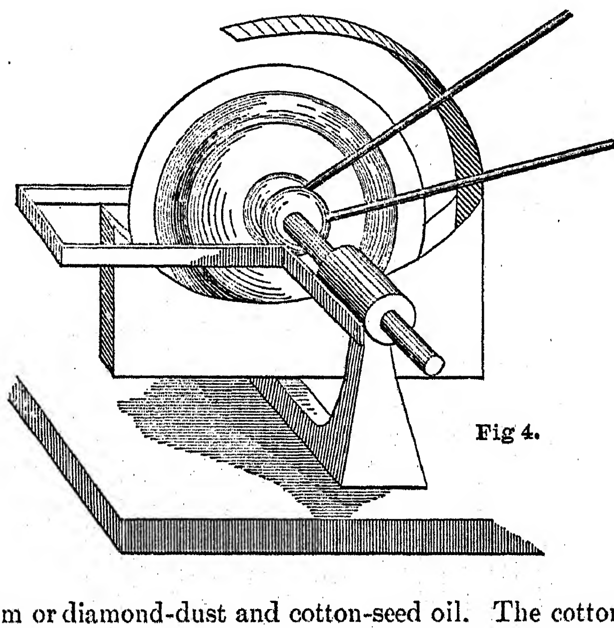


Fig 4.

corundum or diamond-dust and cotton-seed oil. The cotton-seed oil with the cutting material adheres to the periphery of the saw, and as the saw comes in contact with a piece of iridium it gradually does the work. Cotton-seed oil is preferred for this purpose to any other oil, on account of its viscosity.

I may mention briefly some of the uses to which iridium has been applied. First, I will refer to the draw-plate for drawing wire. There are at present, besides the iridium draw-plate, the ordinary steel plate which is used for drawing heavy wire, and the ruby plate, which is used in drawing gold and silver wires, where it is desirable to have them of uniform thickness. The iridium plate is made somewhat similar to the ruby plate, consisting of a piece of iridium

which has been countersunk and drilled in the usual way to the size of the hole required, and set in a brass plate, where it is firmly held by a bushing. This plate is now coming into use, and is rapidly taking the place of the ruby plate, being equal to the ruby in hardness and much more durable, since it is less liable to break or chip by rough handling or heating.

Iridium knives are made for fine scales and balances, the bearing edge of which consists of iridium, soldered firmly to a brass body. These are rapidly taking the place of the agate for fine chemical balances, and there seems to be no reason why they should not have even a more extended use, since they are superior to the agate in that they take a finer edge and thereby make a more delicate balance, and are not so liable to crack or break. They are now being used altogether by Mr. Henry Troemner, of Philadelphia, the well-known scale manufacturer, for the purpose of adjusting his weights for all of his scales.

Hypodermic needles for physicians' and surgeons' use are now made of gold and tipped with iridium, in place of the old steel pointed ones, which are liable to rust or corrode if not properly taken care of. The iridium being hard will take a good edge, and is not subject to corrosion, as is steel.

Styluses for manifold writing are also being made with iridium points, having decided advantages over either steel or agate. Iridium points are also being applied to surveyors' and engineers' instruments, and in all places, in fact, where hardness, durability, and non-corrosibility are required. For all the above uses the iridium alloyed by fusion with phosphorus is employed.

Some years ago experiments were made in order to apply this metal to the electric light. We found that an iridium electrode used upon the negative of an arc-light would keep its shape and resist the heat, provided the positive carbon which was used with it was not allowed to strike or fall too heavily upon the iridium negative. Since the metal at a white heat becomes malleable, a continual pounding or striking would gradually beat the negative out of shape. The iridium negatives are made by setting a piece of de-phosphorized iridium in the end of a brass rod about six inches long and nine-sixteenths of an inch in diameter. The length of the iridium is about half an inch, ground conical in shape. It was found that the brass, being only half an inch from the arc, would resist the action of the heat; but in some cases where the lamp flamed the brass was liable to undergo partial fusion; and in such cases it was found de-

sirable to put a thimble or cap of platinum over the end of the brass and just below the iridium, the platinum thimble being about half an inch long.

One of the most important applications of iridium which has yet been made is to the electrical contact-points of telegraphic apparatus. These contact-points consist of pieces of copper wire tipped with iridium, which are set in the instrument just as platinum points are set. These contacts will outlive many platinum contacts; are not subject to oxidation or sticking as are the platinum ones; and all that is necessary in order to clean them when they become dirty is to pass over their surface an emery file or a piece of fine emery-paper. These contacts have been thoroughly tested by various eminent electricians and also by long continued use, and the advantages herein stated have been in every case fully demonstrated.

In the past three years we have been experimenting on methods of plating with iridium, and about one year ago we succeeded in obtaining a bright reguline deposit of iridium on base metals. This deposit resembles the natural metal, being quite hard and resisting the action of acids. There were many difficulties encountered in accomplishing this result, on account of the power of the metal to resist the action of the solutions; but we have succeeded in obtaining a solution which gradually attacks an anode of iridium, and it is hoped in a short time that all the minor practical difficulties will be overcome in the plating of articles on a commercial scale. So far, we have been thoroughly testing our results, and do not feel prepared to place our work before the public until it is perfect in all its details.

Discussion.

James C. Bayles, New York City: I would like to ask Mr. Dudley how the anode is prepared in electro-plating; whether from iridium in grains, or in the fused state.

Mr. Dudley: We use iridium which has been fused with phosphorus. It contains 5 per cent. of phosphorus, which does no damage. Of course, in working out a problem of this nature, it takes several years to ascertain all the causes of disturbance; but we have not yet attributed any trouble to the phosphorus in the solution. We have made many experiments with alloys of iridium, but have practically failed to get an anode of them which would readily dissolve; but we find that the anode of fused iridium gradually dissolves, and yet not fast enough to keep the solution replenished,

which has been countersunk and drilled in the usual way to the size of the hole required, and set in a brass plate, where it is firmly held by a bushing. This plate is now coming into use, and is rapidly taking the place of the ruby plate, being equal to the ruby in hardness and much more durable, since it is less liable to break or chip by rough handling or heating.

Iridium knives are made for fine scales and balances, the bearing edge of which consists of iridium, soldered firmly to a brass body. These are rapidly taking the place of the agate for fine chemical balances, and there seems to be no reason why they should not have even a more extended use, since they are superior to the agate in that they take a finer edge and thereby make a more delicate balance, and are not so liable to crack or break. They are now being used altogether by Mr. Henry Troemner, of Philadelphia, the well-known scale manufacturer, for the purpose of adjusting his weights for all of his scales.

Hypodermic needles for physicians' and surgeons' use are now made of gold and tipped with iridium, in place of the old steel pointed ones, which are liable to rust or corrode if not properly taken care of. The iridium being hard will take a good edge, and is not subject to corrosion, as is steel.

Styluses for manifold writing are also being made with iridium points, having decided advantages over either steel or agate. Iridium points are also being applied to surveyors' and engineers' instruments, and in all places, in fact, where hardness, durability, and non-corrosibility are required. For all the above uses the iridium alloyed by fusion with phosphorus is employed.

Some years ago experiments were made in order to apply this metal to the electric light. We found that an iridium electrode used upon the negative of an arc-light would keep its shape and resist the heat, provided the positive carbon which was used with it was not allowed to strike or fall too heavily upon the iridium negative. Since the metal at a white heat becomes malleable, a continual pounding or striking would gradually beat the negative out of shape. The iridium negatives are made by setting a piece of de-phosphorized iridium in the end of a brass rod about six inches long and nine-sixteenths of an inch in diameter. The length of the iridium is about half an inch, ground conical in shape. It was found that the brass, being only half an inch from the arc, would resist the action of the heat; but in some cases where the lamp flamed the brass was liable to undergo partial fusion; and in such cases it was found de-

sirable to put a thimble or cap of platinum over the end of the brass and just below the iridium, the platinum thimble being about half an inch long.

One of the most important applications of iridium which has yet been made is to the electrical contact-points of telegraphic apparatus. These contact-points consist of pieces of copper wire tipped with iridium, which are set in the instrument just as platinum points are set. These contacts will outlive many platinum contacts; are not subject to oxidation or sticking as are the platinum ones; and all that is necessary in order to clean them when they become dirty is to pass over their surface an emery file or a piece of fine emery-paper. These contacts have been thoroughly tested by various eminent electricians and also by long continued use, and the advantages herein stated have been in every case fully demonstrated.

In the past three years we have been experimenting on methods of plating with iridium, and about one year ago we succeeded in obtaining a bright reguline deposit of iridium on base metals. This deposit resembles the natural metal, being quite hard and resisting the action of acids. There were many difficulties encountered in accomplishing this result, on account of the power of the metal to resist the action of the solutions; but we have succeeded in obtaining a solution which gradually attacks an anode of iridium, and it is hoped in a short time that all the minor practical difficulties will be overcome in the plating of articles on a commercial scale. So far, we have been thoroughly testing our results, and do not feel prepared to place our work before the public until it is perfect in all its details.

Discussion.

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without the addition, now and then, of some of the pure salt, the amount depending upon the kind of solution employed. The same thing is necessary in silver- and in nickel-plating. Theoretically, the anode should dissolve and keep the solution up to the proper strength. In practice, that is never the case.

MR. BAYLES: How is the solution made?

MR. DUDLEY: This solution is made by dissolving the iridium first with chlorine and sodium chloride. The iridium or iridosmine is mixed with common salt, placed in a tube, and heated to redness. Chlorine gas is then allowed to flow slowly through the tube for several hours, at the end of which time most of the iridium will have combined with the salt and chlorine to form the double chloride of iridium and sodium, which rapidly dissolves in water. From this solution we can obtain any salt of iridium which we desire. In plating with the metal, we find that a solution, very slightly acidified with sulphuric acid, gives the best results practically, although neutral or alkaline solutions work very well.

A MEMBER: What kind of solder is used in soldering iridium to other metals?

MR. DUDLEY: Ordinary silver-solder. Soft solder will solder the metal as well, but we seldom use it, since it is not as durable.

DR. R. W. RAYMOND, New York City: I would ask whether it is known what is the possible supply of that metal.

MR. DUDLEY: Well, we find it, like a good many other metals, widely distributed—in Canada, and many parts of the United States, in France, and a great many European countries, and, as I have said, the largest supply has heretofore been in Russia. The Russian government are very arbitrary, and they enforce their laws right up to the mark, and generally when they make a law, they make it pretty strong to start with. (Laughter.) As iridium was found principally in Russia, we sent over a representative to see what could be done about getting our supply from there. He went to the United States consul at St. Petersburg, and was informed that there was a law, requiring persons who had any iridium in their possession, to turn it over immediately to the authorities, on pain of being exiled to Siberia for life. (Laughter.) The result was that in a short time the mint had stored up in its vaults quite a supply of the metal. Our representative went to the consul, who telegraphed to the platinum mines, where most of the iridium is obtained, but received no answer. He wrote a letter, but still no answer. Telegraphed again. No answer. He finally found that as every telegram or communication

was liable to be opened and read, those receiving the same were afraid to have anything to do with the matter for fear of going to Siberia. The result was that he could do nothing. But there are some parties in Hamburg, who deal in the ore, and we get most of it from them. It is said that they get it from the mint at St. Petersburg. I may say, also, that we get from three to four hundred ounces annually from the United States government. We do not get more for the reason that the mints will not knowingly buy gold-dust which contains any iridium. They examine the dust very carefully, but, in spite of their care, they get a little.

THE BENEFICIAL FUND OF THE LEHIGH COAL AND NAVIGATION COMPANY.

BY JOSEPH S. HARRIS, PHILADELPHIA, PA.

As a result of the study of social problems to which so much thought has been given in this country and Europe in the last half century, many employers of labor have come to think that some provision should be made for their workingmen in case of injury. There has been a growing tendency so to administer the laws governing industrial pursuits in these countries as to add self-interest on the part of capitalists, to the plea urged by humanity, that every possible care should be taken to guard the workers from accident; but as no care can guarantee immunity, there is a necessity to supplement these precautions by some method of providing pecuniary aid that shall be available when disabling accidents do occur.

It was once a favorite idea of theorists on political economy, that in the ideal state of society every man should take care of himself, and that the less care or control there was assumed by any man over others' private affairs, the better; but this gospel of selfishness has had its day, and it is now generally recognized that in the existing state of affairs the stronger and richer cannot escape the duty of being to some extent, the keepers of their less fortunate brethren; and, on the other hand, that an assumption of care for them involving to some extent an exercise of authority, is not a thing to be necessarily and always resisted. Out of these convictions, many efforts for the amelioration of the condition of workingmen have grown—which or one result have produced various plans which combine the con-

tributions of employers and employed, in a fund from which relief for injured workmen may be drawn.

The officers of the Lehigh Coal and Navigation Company have given a good deal of thought to the formation of such a fund for the persons employed about their mines, and have made use of the experience of other companies so far as it could be had. There are two cases directly in point, in the fund established by the Philadelphia and Reading Coal and Iron Company in 1877, which is still in operation, and the Employees' Benefit Fund of the Wilkesbarre Coal and Iron Company, which grew out of the Avondale disaster in 1869, and which continued in operation till 1877, when the pecuniary and other difficulties of the time led to its abandonment. The scheme of the Philadelphia and Reading Coal and Iron Company, as set forth in the original circular of President F. B. Gowen, is presented here, followed by extracts from the proceedings of the Trustees of the Employees' Benefit Fund, which, though placed somewhat out of their chronological order, represent the plan fairly enough. Then follows the lately-issued circular of the Lehigh Coal and Navigation Company, with some remarks which a study of the subject has suggested to the writer.

The following circular shows the plan of the Philadelphia and Reading Coal and Iron Company:

To the Miners and Laborers of the Philadelphia and Reading Coal and Iron Company:

The Philadelphia and Reading Coal and Iron Company will give twenty thousand dollars ($20,000) as an endowment of a beneficial fund for insurance against accidents and death of such of their miners and laborers as may desire to accept its benefits, by complying with the following provisions:

First. Miners and inside laborers to pay to the fund thirty cents per month.

Second. Outside laborers to pay twenty cents per month.

Third. Boys and old men to pay either five or ten cents per month, as may be determined by the proper district superintendents.

All payments to be made monthly by deductions from the pay-roll; but no payments to be made in any month in which the person paying does not work, and in cases where not more than one week's time is made in any month, the payments for said month to be reduced one-half.

In case of any accidental injury sustained by a contributor when actually engaged in the employment of the Company, which incapacitates him from work, the party injured shall receive during the period of such incapacity the following sums:

Those who have paid thirty cents, or twenty cents per month, shall receive five dollars per week.

Those who have paid ten cents per month, shall receive two dollars per week.

Those who have paid five cents per month, shall receive one dollar per week.

Provided, that no payment shall be made for a longer period than six months,

and that the certificate of a reputable physician that the disability is the result of an accidental injury, such as above described, shall be furnished at the end of each month.

In case of death directly resulting from any such accidental injury, the following sums will be paid: On account of those who have contributed thirty or twenty cents per month, thirty dollars *in cash*, and seven dollars per week for one year; for those who have contributed ten cents per month, the sum of thirty dollars in cash and two dollars and eighty cents per week for one year; and for those who have contributed five cents per month, the sum of thirty dollars in cash and one dollar and forty cents per week for one year.

The said payments of thirty dollars to be made within one month after the death, and the weekly allowances to be paid monthly during the year, and in all cases a certificate of the coroner or a reputable physician will be required that death resulted directly from an accidental injury sustained as aforesaid, and not from disease. It being provided that in case of death the payments shall be made exclusively to such relative, relatives, or heirs-at-law of the deceased as are first named in the following list:

First. To the widow.

Second To the children.

Third. To the parents.

Fourth. To the brothers and sisters.

Fifth. To other heirs-at-law.

In no case shall the money be applicable to the debts of the deceased, or liable to be attached by his creditors, and in all cases the decision of the trustees, either as to the liability of the fund or as to the proper recipient of its bounty, shall be final and conclusive upon all parties.

Those of the employees of the Company desiring to avail themselves of the benefits of this beneficial fund, must signify their wish by signing a book, to be provided for that purpose, at the office of each colliery and iron-ore mine of the Company. Each will be left free to contribute or not, as he may desire, but in no event will any money be paid out of the fund to any other than a contributor.

The twenty thousand dollars endowment and all moneys received from contributors will be placed in the charge of Hon. Cyrus L. Pershing, President Judge of Schuylkill County, C. H. Tyson, President of the Safe Deposit Bank of Pottsville, and Franklin B Gowen, President of The Philadelphia and Reading Coal and Iron Company, as trustees, who will make a public yearly statement of the receipts and expenditures; and any vacancy in the Board of Trustees will be filled by an appointment to be made by the President for the time being, of The Philadelphia and Reading Coal and Iron Company.

All clerical expenses connected with the collection and payment of money on account of the fund will be borne by the Company.

FRANKLIN B. GOWEN,
PHILADELPHIA, March 17th, 1877. President.

The following is the plan of the Wilkesbarre Coal and Iron Company:

At an adjourned meeting of the Trustees of the Relief Fund of the Wilkesbarre Coal and Iron Company, held in Baur's Hall on Wednesday evening, August 21st, 1872, the following order was issued to the employees of the several works of the

Wilkesbarre Coal and Iron Company, viz.: That the employees of each division of said Company are hereby notified to appoint or elect some responsible person to act as Trustee until the first of January, 1873. Their successors to be elected in the first week of January and July in each year. The following rules were adopted for the government of the fund for the ensuing year:

First—That there shall be chosen one man from each division of the Company to act as Trustee, to act in conjunction with the foreman of his division, whose term of service shall be six months, or until his successor be elected. Second—The duty of Trustee shall be, that whenever an accident occurs in any of their respective divisions, they shall, in two days afterwards, report the same at the office of the Company, on blanks signed by the Trustee and foreman, at the same time giving the date and nature of such accident; and when the person or persons so injured shall again resume work, they shall report accordingly to the office of the Company, where an order will be immediately drawn by the clerk for the amount legally due; and in no case whatever, shall money be paid unless the above rules are complied with. Therefore, it is to be hoped that all the employees will take an individual interest in directing the management of this fund, and care should be taken in the selection of Trustees, as it requires a person to be attentive and punctual on all occasions.

Third—Any person or persons in the employ of the Wilkesbarre Coal and Iron Company for the space of one month, who has not previously contributed to the Benefit Fund, shall so contribute one day's labor before he shall be entitled to its benefits, which shall be as follows:

Fifty Dollars ($50) to be paid for funeral expenses in case of accidental death, and $3 per week for the term of one year to the widow of such person killed, provided she remains unmarried during that length of time.

One Dollar ($1) per week for the term of one year to each orphan child under twelve years of age, unless otherwise cared for.

Six Dollars ($6) per week, during his disability to work, to each man injured in or about the mines.

Three Dollars ($3) per week, during his disability to work, to each boy under sixteen years of age, injured in or about the mines.

The following is the plan adopted by the Lehigh Coal and Navigation Company:

Rules for Establishing and Administering the Beneficial Fund of the Lehigh Coal and Navigation Company.

This fund shall be created and maintained by the following contributions, to be made monthly:

The Lehigh Coal and Navigation Company will pay into it one cent for every ton of coal produced at its mines. The inside workingmen employed on its property will pay into it one per cent. of their earnings, and the outside workingmen will pay into it one-half of one per cent. of their earnings, but no one shall pay more than one dollar in any one month.

All contributing workingmen who may be accidentally injured when actually engaged in the service of the Company, shall be entitled to the following benefits, to be paid out of the fund:

In case of accident so received, which shall cause disability lasting more than one

week, the person injured shall receive a sum equal to one-half the weekly wages of the class of workmen to which he belonged, for each week of such disability, but no one so injured shall receive from this fund such benefits for a longer period than six months for any one accident.

In case of accident so received, which shall result in death, thirty dollars will be paid for funeral expenses, and a sum equal to one-half the weekly wages, as in the case of injury, will be paid to the legal heirs of the deceased, for one year from the date of the accident.

These benefits will be paid only on the statement of the proper foreman that the injury was received in the service of the Company, and on a certificate from the physician to the fund, in case of accident, that the accident was a disabling one, and in the case of death, that the death resulted from accident, and not from disease. In case of accident, the certificate of disability must be renewed every two weeks.

All moneys which shall be paid into this fund shall be placed in charge of a Board of Trustees, to be appointed, from time to time, by the President of the Lehigh Coal and Navigation Company, and to be chosen by him partly from the officers of the Company and partly from the business men of experience and of good reputation in or near the mining region. A report of the receipts and expenditures of this fund shall be published by the Board of Trustees at least once a year. The first Board of Trustees to be so appointed will be Mr. George Ruddle, of Mauch Chunk, Hon. Michael Cassidy, of Nesquehoning, and Mr. Daniel Shepp, of Tamaqua. They shall receive no remuneration for their services.

The Physician to the fund shall be appointed, from time to time, by the President of the Lehigh Coal and Navigation Company from the practicing physicians in the region. The Physician to the fund for the present will be Dr. Edward H. Kistler, of Summit Hill. He will make no charge to the contributors for the necessary certificates, but if the contributors desire medical attendance they must themselves pay such physicians as they may select to attend them.

Any workingman not desiring to contribute to this fund nor to share in its benefits, can, after any monthly pay-day, receive from the Lansford Office the sum deducted for the fund from his last month's pay, but his name will not be again enrolled among the contributors, nor will he be entitled to any benefit from the fund until after he shall have made another payment.

The fund thus established, is believed to be ample to meet all claims arising from accidents to the contributors, and if, as is hoped, there shall be more than is required under this plan, the benefits will be increased as, from time to time, the Trustees may think prudent.

The Lehigh Coal and Navigation Company in making this contribution and establishing this fund desires to relieve the suffering which accidents cause among its workingmen, and to render unnecessary the collections which make a heavy tax on the benevolent, and also, to promote the growth of the kindly feeling which now exists between the Company and the men engaged in its service.

The operations of this fund will commence January 18th, 1884.

By order of the Board of Managers.

J. S. Harris,
President.

Office of The Lehigh Coal and Navigation Company,
Philadelphia, Pa., January 15th, 1884.

The first two plans have had the advantage of successful practical operation for several years, and the third is in its infancy; but it is

thought that in some respects, which will be indicated below, it is an improvement on the others. In the remarks which follow, no *explicit* reference will be made to either of the two earlier plans, the features criticised being in some cases common to the two, and in other cases peculiar to one of them.

1. Any plan which adopts only two or three rates of contribution is objectionable, because it bears unequally upon the earnings of the contributors, making a comparatively heavy tax on those in each class whose rate of pay is least, or whose earnings through interrupted employment may be lowest; and too light a tax on those who are better paid or more regularly employed.

2. Similarly, there is an objection to having but two or three rates of benefits, as this will give to the laborer whose average compensation is low for his class, nearly or quite as large an income when disabled, as when he is at work; making the temptation great for him to put himself in the way of receiving slight disabling injuries; and experience has shown that the less worthy class of workmen do not always resist this temptation.

In the third plan an attempt has been made to escape these two evils by fixing each person's contribution as a definite percentage of his monthly earnings, and his benefit in case of injury at a percentage of what a man employed at labor similar to his, can ordinarily earn.

If this percentage of benefit be one-half of the earnings of his class, this plan does not remove the temptation above mentioned in case there is half-time work, but the evil is less than under the other plans.

3. Where a barely sufficient sum of money to pay accruing benefits is provided, whether by the employer virtually agreeing to make up deficiencies, or by contributions being levied on both parties whenever the fund is exhausted, it results in the first case, as the extra payment comes out of the employer's pocket, that however wasteful the administration of the fund is, the employee is none the poorer; and however carefully it may be administered, there is no accumulation in the fund, so that there is no incentive to save, and no further benefit to hope for; and in the second case there is the additional danger that the exhaustion of the fund may occur at a time when, from inability or from dissatisfaction, either or both parties may decline to make the comparatively large contribution of one day's product of coal or labor.

In the third plan the contributions are small and frequent, so

that neither party is likely to feel them much; and yet a careful investigation leads to the belief that they will furnish a fund which will be so much more than will be required to pay the stipulated sums, that the benefits can be increased as the fund accumulates. As this fund inures wholly to the benefit of the workingmen, they will have some motive to prevent the improper depletion of what is to be a resource for themselves in case of injury.

4. Where benefits are to be paid upon the certificate of any reputable physician, it will happen that in order to preserve the custom of a family and its friends, some of the less respectable of the profession will unduly favor the applicant for benefits; and the drawing of the line between physicians who are, and who are not, reputable, would be a very ungracious task.

Nor does the making the application pass before a board of workmen materially mend matters, or give the fund satisfactory protection; for a feeling of good-fellowship, a desire to avoid offence, and a thought that a committeeman's turn to be injured may come next will ordinarily lead to a decision in favor of the applicant. On the other hand, where the decision of such a board is adverse, it arouses much more feeling than if the rejection had come from another source than the man's fellow-workmen.

In the third case it was practicable, on account of the compactness of the territory over which the operations of the plan will extend, to appoint the best and most respected physician of the region as arbiter between the fund and its beneficiaries.

5. To take contributions from no man without his written authority, has much to recommend it; and among men accustomed to act intelligently as to their own affairs this would be the only true course. To take them without provision for refunding in case of dissatisfaction is certainly an arbitrary exercise of authority. The first course requires a long time to bring into successful operation, and always excludes a considerable percentage of the workmen; the second plan of course creates a certain amount of discontent.

The third plan adopts the middle course of including everybody in the contribution, but in case of dissatisfaction, allowing every man to withdraw his contribution if he is not entirely satisfied after having the plan explained to him.

Tabular statements embodying the experience of the Philadelphia and Reading Coal and Iron Company are presented herewith. They have been of great use in deciding what assessment should be made,

and what benefits could be paid, and will well repay careful study. A full discussion of the information to be derived from these tables, would unduly prolong this paper, but it may be of interest to show in what way the information used in determining the sum that would be needed to carry out the provisions of the third plan, was obtained from them. Inspection of the tables shows that for mines situated like those whose experience is tabulated, we may expect 1.13 fatal, and 56 6 disabling accidents for each 100,000 tons of coal mined; and 3.26 fatal, and 163.5 disabling accidents for each 1000 workmen employed; and further that the fatal accidents will call for benefits to the amount of $191.32 each, while the average cost of disabling accidents will be $15.57.

Now, in the year from November 30th, 1882, to November 30th, 1883, the mines of the Lehigh Coal and Navigation Company produced 927,000 tons of coal, and the pay rolls for that time aggregated $1,264,906; by the Reading experience we should expect:

Fatal accidents 10 49, costing, ...	$2006 95
And disabling accidents 524.7, costing, ...	81b9 58
Requiring a total benefit payment of, ...	$10,176 53

An investigation made some years ago showed that, of the wages paid by the Lehigh Coal and Navigation Company, 55 per cent. was paid to inside workmen, and 45 per cent. to outside workmen, the unusually large proportion of the latter arising from the fact that it includes men employed in the machine-shops, in the screen-building, in transportation, and in other ways not usually so closely associated with coal-mining. Dividing the year's pay-rolls in this proportion, and taxing the inside workmen one per cent., and the outside workmen one-half of one per cent. of their wages, we have:

Inside men, $695,698,30 @ 1 per cent., ...	$6956 98
Outside men, $569,207,70 @ ½ per cent., ...	2846 04
Company's contribution, 927,000 tons @ 1 cent per ton .	9270 00
Total fund available for benefits, ...	$19,073 02

Let us also examine the experience of the Lehigh and Wilkesbarre Coal Company, who from 1874 to 1b77, worked the mines of the Lehigh Coal and Navigation Company, and whose experience therefore is valuable, though we have not so much detail recorded as is

given by the Reading Company. In 1876, under a system which made all workmen contributors, there was paid:

For fatal accidents, ...	$1282 83
And for disabling accidents, ...	8491 50
Total, ...	$9774 33

The number of each kind of accidents not being recorded.

In that year the mines produced 606,773 tons of coal, so that the

Fatal accidents cost per 100,000 tons, ...	$ 211 42
And disabling accidents cost per 100,000 tons, . . .	1399 45
Making the total cost per 100,000 tons, ...	$1610 87
So that for 927,000 tons the total cost would have been, .	$14,932 76

A result 47 per cent. greater than that found from the Reading experience, owing mainly to the fact that their rate of benefits was considerably higher than that of the Reading Company. Judging from the experience of either Company, the plan proposed by the Lehigh Coal and Navigation Company should raise money enough to show a handsome surplus of earnings, to be distributed hereafter in increased benefits.

This paper is offered as a contribution to a subject which is beginning to attract attention in this country, and on which it seems desirable to get all the light that can be derived from our limited experience.

Tables Showing the Experience of the Reading Co.'s Beneficial Fund.

Year.	Men employ'd	Contributors.		Tonnage shipped.		Disabling accidents		Fatal accidents			Serious accidents.		
		No	p c. of men	Total.	Per man	No.	Per 1000 cont.	No	Per 1000 men	Per 100,000 tons	No.	Per 1000 men	Per 100,000 tons.
1877	11,428	2,290	20	3,794,529	332	119	52 0	45	3.94	1 19	185	16 19	4 87
1878	10,630	7,033	66	2,727,608	257	651	92.6	44	4.14	1 61	217	20 41	7.96
1879	12,601	7,121	56	4,269,929	337	1323	185 8	52	4.11	1.22	238	18 80	5.57
1880	13,093	7,436	57	3,460,464	264	1171	157 5	43	3 28	1.24	198	15 12	5 72
1881	13,509	8,471	67	3,937,608	291	1437	169 6	33	2 44	0.84	236	17.47	5 99
1882	13,705	8,548	62	4,111,830	300	1620	189 5	43	3 14	1.05	191	13 94	4 65
1883	16,345	10,748	66	4,582,667	280	1867	173 7	46	2 81	1 00	195	11.93	4 26
Totals and means	79,943	49,357	62	23,090,106	289	8069	163.5	261	3 26	1.13	1275	15.95	5 52

The results for 1877 are tabulated here, but are not considered in making up totals and means, as only part of the year is included in the returns. "Men" is used for "employees" above only because it is shorter. It includes "boys." The contributors averaged 61.74 per cent. of the total employees. On this basis there would have been for the whole number of employees 13,069 disabling accidents, or 56.6 per 100,000 tons of coal mined, assuming (which is not necessarily true) that the contributors' risks were a fair average of those of the whole number of employees.

Year.	Men's contributions.			Total benefits.		Per ct men's contribution.	Fatal accidents.			Disabling accidents.		
	No. of cont.	Amount	Per cap	Amount	Per cap.		No.	Amount benefits.	Per capita.	No	Amount benefits.	Per cap.
1877	2,290	$ 2,050 95	$0.90	$ 1,802 21	$0.78	1.14	3	$ 308 16	$102.72	119	$ 1,494.05	$12.55
1878	7,033	10,738.75	1 53	18,898 89	2 69	.57	29	6,886.46	237.46	651	12,012.43	18 45
1879	7,121	18,295 85	2.57	32,781.32	4 60	.56	68	11,891.90	174 88	1323	20,889.42	15.79
1880	7,436	21,728 85	2 92	32,784 14	4.41	.66	75	13,909.78	185 46	1171	18,874.36	16.12
881	8,471	23,194 04	2.74	34,915.46	4 12	.67	62	11,375.20	183.47	1437	23,540.26	16.38
882	8,548	25,074.09	2.93	37,540.17	4.39	.67	62	12,571.29	202 76	1620	24,968.88	15.41
883	10,748	29,232 45	2.72	37,578.68	3 50	.78	64	12,241 34	191 27	1867	25,337.34	13 57
tals nd ans.	49,357	128,264.93	2.59	194,498.66	3.94	.66	360	68,875.97	191.32	8069	125,622.69	15.57

Fatal accidents took 35.4 per cent. of the benefit payments, disabling accidents 64.6 per cent.

The results for 1877 are not included in "Totals" and "Means."

Discussion.

F. Z. Schellenberg, Superintendent of the Westmoreland Coal Company, Irwin Station, Westmoreland Co., Pa. (a written communication, read by the Secretary): In relation to benefit funds of and for employees, I would say that I have been permitted to carry out a simple means of collection and disbursement for the relief of the miners and laborers employed by this Company, at the group of mines about Irwin's Station, to meet cases of accident at the works, or death from any cause. Each man taking employment here is at once subject to the regular levy of 25 cents, for the current calendar month; and during his time of employment may thus become a beneficiary, but no longer. The reports come through the foreman of the mine, and the members of the Relief Committee attend personally to obtaining correct information. The payments are made upon the Record transmitted with other accounts to the office, and generally monthly, on pay-day. The regulations adopted at a meeting of the outgoing and incoming Committees annually held in consultation with me, have now remained substantially unchanged for several years, and since "strains," which are very liable to be complicated with rheumatism, etc , have been eliminated from the list of grounds for relief, no extra levy has been needed. The Committee has presented to the bookkeeper $100 for his services, and there is a rising balance on hand.

Last year we had but one death from accident in mining and shipping 600,000 tons of coal here. We are enabled to forbid all canvassing for relief-subscriptions at the works. I may remark, after nine years of experience, that since we take care to keep benefits below earnings, there is no inducement to extend the period of benefit, and there is room left for charitable action in each neighborhood.

Aside from the relief-fund, there is an optional subscription to doctors' lists: the physicians of the vicinity return monthly to our office the names of their patrons who agree to pay the uniform sum of one dollar per month for all medical attendance, and who have the privilege of changing their patronage from one doctor to another, any month. The monthly payments once subscribed, however, run

for the year or less time of employment, and are collected for the month in advance.

Mr. Schellenberg appended the annual statement for 1883, of the relief-fund referred to, showing balance in hand at the beginning of the year \$274.05; amount of twelve monthly 25-cent collections \$2603.75; total \$2877.80; and disbursements (in 94 cases) of \$2,020, leaving a balance on hand of \$857.80. The following are the regulations:

"*Levy* to be twenty-five cents per month, or more, if needed [amended: to keep balance on hand above \$500.] *Benefits:* For two weeks' disability, or more, five dollars per week, after first week, shall be paid. Benefits to cease after twenty-six weeks from date of accident. Disability must be from actual casualty at the mines, not injury from strain or otherwise that may be due to weak condition of the body. Beneficiaries are prohibited from doing any work unless specially permitted by whole committee. In case of loss of limb, the full amount of \$125 may be payable at any time, and, at discretion, \$75 more may be paid toward getting an artificial limb. *Death:* To the widow or legal heirs one hundred dollars will be paid when a member dies from accident, and fifty dollars when death is from other natural cause. The directors of the Westmoreland Coal Company, at their meeting in June, 1879, resolved: 'That in the event of any of our men or boys being killed while working for us, this Company will contribute for the relief of their families an equal amount to that paid from their relief-fund.' Notice of accident to be given to the committee-men within three days of the accident. Committee-men for the year to be selected on pay-day, in January; in case of vacancy, on first pay-day thereafter."

President R. W. Hunt, Troy, N. Y.: All of us know how constantly accidents are taking place; and no matter how high the earnings have been or how improvident the men, when an accident comes, it is beyond human nature to turn coldly away. The result is constant subscriptions through the works, which are a tax on the generous, including those who cannot afford to give. I think, if I mistake not, the Edgar Thomson works used to insist upon insuring the lives of their men: I do not know whether they still keep it up.

W. R. Jones, Pittsburgh, Pa.: We encourage our men to insure themselves. In the early history of the Edgar Thomson works, we were subject to a great many accidents, mostly owing to lack of care on the part of the men. We encouraged them to insure themselves in a well-known company, and in certain cases we at first assisted

them. But I am not in favor of coddling the American workingman. Let him learn to be prudent like other men. If we can train the workman to be self-reliant, it will be better for the manufacturer and for his people.

President Hunt: No doubt there is a great deal in what Captain Jones has said. At the same time, many of us, and particularly those in the mining industries, have to deal with a class of laborers that it is a stretch of the imagination to call "American workingmen;" and while we are educating them up to this point of American manhood, they have the lives of a good many people depending upon their exertions. That is one thing to be taken into consideration. We cannot place them on the same level as the ordinary business man. The merchant or even the ordinary mechanic does not take his life in his hand as the miner is compelled to do. It is not always the miner's own mistake that kills him or cripples him. The "accident" can often be traced back to insufficient machinery, insufficient regulations of the employees, or even insufficient laws of the State. And he works for quite a small wage while he is taking this risk. Hence I think that all associations that you can establish between the employer and the employee, making him feel that his employer is more to him than simply a man giving him cold dollars for unwilling work rendered, the more you tend to bring that man up to the higher elements of manhood. I start out as an employer with the statement that I will not have any organization in my works; that the workmen shall not dictate to me on what conditions the works shall be run. If a man does not choose to submit to this, let him go to work for somebody else, but so long as he is in my employ, he must work upon my terms. Now, having laid down these premises, and made our contract complete, I say to him, "I want to be to you more than an employer; I will encourage you in any and every way to take care of yourself and to take care of your family." And while in this, as in every humanitarian endeavor, one is certain to be met with ingratitude, and sometimes with suspicion and malice, that will blunt one's desire to do good, so that it will require a strong spirit to keep one's purpose firm; still I believe the plan is right, and I believe that these coal companies and railroad companies which have taken this direction, are in the right way. With regard to "the freedom of the American workmen," they are not free—most of them. I do not think that the employer need be afraid to exercise a little wholesome and benevolent tyranny, so long as they themselves submit to their trades-unions which are the greatest of all tyrannies.

I am glad to refer in this connection to a former President of the American Institute of Mining Engineers—I mean Eckley B. Coxe—who, in his organization of labor, at Drifton, Pa., certainly has done noble work and is doing it to-day, with the result that he runs along untrammelled by strikes or by trades-unions; proving that human nature at last will appreciate a big heart when it comes into contact with it.

MR. JONES: I am very proud to say that I consider Eckley B. Coxe as a practical illustration of the principle of *elevation*, that I am contending for. Let the capitalist deal fairly and squarely with the laboring man, and leave him his independence and his responsibility—not first make him helpless, and then nurse him because he is helpless.

DR. R. W. RAYMOND, New York City: It is very evident that gentlemen of our profession occupy an ideal position for a critical survey of this question, being equally removed from the ordinary ranks of labor on the one hand, and alas! from the ranks of capital on the other. I would like to call attention to one little point in the plan pursued by Messrs. Cooper and Hewitt at the Durham Iron-works, and doubtless by many other employers. We have an arrangement by which the workmen are allowed to choose their own physician to prescribe for them, which combines the freedom of the individual with the advantage of organization. We have a system at our works by which a single man pays half-a-dollar, and a married man a dollar, per month for medical attendance. It is perfectly voluntary—a contract between the men and the doctor, simply enforced through the office. There is a considerable majority who prefer one physician in the neighborhood. It amounts in a year to something like $1500 or $2000 for that physician, which is not a small item for a country practitioner, particularly as he never has the slightest particle of difficulty in collecting his bills. Taking into consideration the certainty of this payment (made through the office of the works, monthly) the doctor finds it a profitable piece of work, and he does it in connection with a large and valuable country practice.

Now I would like to call your attention to its effect upon the doctor! It makes it the doctor's interest to study hygiene instead of drugs and medicine. It is not the doctor's interest to come and call frequently or for a long time. It is the doctor's business, when anybody is sick, to get them in order as soon as possible, so that his income may come to him without serious labor. As a matter of fact,

our doctor at Durham, apart from cases of surgery—burns and bruises and broken limbs—has very little to do, except to make up in the spring two pailfuls of cough-mixture, which he administers impartially to all the children. (Laughter.) There could be but one better system in this respect, and that I do not suppose we shall ever adopt. I mean the Chinese system, which pays the doctor a good salary as long as the family is well, and shuts it off when anybody gets sick. That makes it still more intensely the interest of the doctor to have as little sickness as possible; but since we cannot rise to the entire height of the Chinese in this matter, I am glad to say that the approach we have made to it works very well in practice. (Laughter.)

I will append to these remarks, when published, an account of the system adopted by the Baltimore and Ohio Railroad Company, since it is one of the most elaborate and successful plans in use among the railroad companies. This account is condensed from a publication made in April, 1883.

"The Employees' Relief Association," connected with the above-named railroad company, was organized May 1, 1880, and incorporated by an act of the Maryland legislature May 3, 1882. The object of this association is to provide a fund for relief in cases of sickness, injury, old age or death to the Baltimore and Ohio Railroad employees and their families. The full payment of all benefits for sickness, accident or death, is guaranteed by the Company, which at the outset gave the sum of $100,000 as a basis of operations, which amount is invested in securities which yield a revenue of six per cent. per annum. This, together with the amounts received from members as dues, forms a fund to meet the demands made by members upon the funds of the association for the payment of benefits. Every able-bodied employee of the Baltimore and Ohio Railroad not over the age of forty-five years, who passes a satisfactory physical examination, is eligible for membership. Blank forms are supplied by the officers of the road, which must be filled out, giving the name, residence, age, occupation, department of the road employed in, the amount to be deducted monthly from his pay as dues, and the name of the person or persons to whom, in case of his death, his benefits shall be paid; and all applications made by minors must bear the written consent of the parent or guardian before the applicant can become a member, or enjoy any of the benefits of the society. When the association was organized it was optional with the men to join or not, but by a later order of the Baltimore and Ohio Company all

new employees must subscribe to the relief features before they can be taken into the service of the company.

The assessments, which are deducted from the pay of the members on the pay rolls, are divided into two classes, known as first and second class. The first class consists of men who are connected with the running of trains, such as engineers, firemen, conductors, baggage masters, brakemen, switchmen and flagmen; the second class, of officers of the road, clerks, agents, telegraph operators, machinists and all others not connected with the running of trains. As members of the first class run a much greater risk of meeting with accidents than those in the second class, they are assessed more per month than the latter. The amounts thus collected from the pay-rolls are deposited with the treasurer of the Baltimore and Ohio Company, upon whom all requisitions for disbursements are drawn, and the vouchers thus drawn, after receiving the signature of the chairman of the committee of management and the secretary of the association, are payable by any agent of the Baltimore and Ohio Company or can be negotiated through any banking institution.

The members are assessed in proportion to the salary received by them, under the following schedule:

First Class.—Those receiving $35 and under, $1 per month; those receiving $35 and not over $50, $2 per month; those receiving $50 and not over $75, $3 per month; those receiving $75 and not over $100, $4 per month; those receiving $100 and upwards, $5 per month.

Second Class.—Those receiving $35 and under, 75 cents per month; those receiving $35 and not over $50, $1.50 per month; those receiving $50 and not over $75, $2.25 per month; those receiving $75 and not over $100, $3 per month; those receiving $100 and upward, $3.75 per month.

The nature and extent of the "benefits" may be best explained by illustrative examples. Take, for instance, the case of a brakeman who, in coupling a car, gets his thumb mashed, and is unable to perform any manual labor for a period of twenty-five days, excluding Sundays. He reports the accident to a medical inspector, who examines the case and reports it to the secretary. For this the sufferer receives from the association the sum of $25, and as railroad companies pay only for service actually performed, the man gets from the relief association fund what he would not otherwise have—the means to support his family while he is unable to work. He is under no expense for medical attendance, as the association has an able corps

of medical inspectors, besides contract-physicians along the line of the road; and, when attended by one of the latter, the bill for attendance is not rendered to the individual, but to the Relief Association.

But should a brakemen be killed in the discharge of his duty, the association pays to his widow or the beneficiary named in his application for membership the sum of $1000. For this he paid the association at the rate of $2 per month. It is provided, however, that no claims for accidental death can be paid until all the heirs of the deceased file with the secretary a paper satisfactory to him releasing the Baltimore and Ohio Company from damages; and if a member while in the discharge of his duty should receive any injury, and file a suit in any court against the company, he will not be, according to the constitution of the association, entitled to receive any of the benefits promised by the association.

Take, again, the case of an engineer, who in the discharge of his duty is injured, and is totally unable to perform any manual labor for a period of twenty days. He pays into the association the sum of $4 per month, and is therefore entitled to receive twice the amount of benefit received by a brakemen, and he receives the sum of $2 for every day thus totally disabled. Should he meet with an accident causing his death while in the discharge of his duty, his heirs would receive the sum of $2000.

A conductor pays $3 per month, and if sick twenty days would receive the sum of $30, and were he to meet with death by accident, his heirs would receive the sum of $1500. There is insurance for sickness as well as accident. Take the case of a brakemen who is sick for a period of ten days and unable to perform his usual duties; he will receive the sum of $10, and were he to die from natural causes, his heirs would receive the sum of $200, being at the rate of $100 for each rate. An engineer dying from natural causes, his heirs would receive the sum of $400.

All claims presented and allowed by the association on account of death are paid within sixty days from the date or receipt of notice of death.

The association is under contract with 318 physicians along the line of the road to attend upon members in case of accidents, and also with the most prominent hospitals in Baltimore, Washington, Wheeling, Pittsburgh, Columbus and Chicago, where disabled members may be treated at greatly reduced rates, and also with the Baltimore Eye and Ear Infirmary, where members receive board and indoor treatment at the rate of $4 per week, and all operations are

performed by the surgeon in charge. They also receive board and the best of medical treatment at the hospitals referred to above, at the rate of $2.50 per week, which amount may be paid out of the allowance from the association.

As shown by the first report of the secretary, dated May 1, 1881, there had been issued 14,439 certificates of membership, and the gross receipts to December 31, 1880, amounted to $88,543.26; the disbursements to $41,503.14, leaving a balance of $47,040.12, which amount was used to liquidate claims made or to be made on account of disbursements to members prior to December 31, 1880.

All the salaries of the secretary, medical inspectors, clerks, and all other expenses of the association are borne by the Baltimore and Ohio Company, and therefore the funds of the association are under no other expense than for the payment of allowances to members and physicians' fees for attendance upon disabled members.

Between May 1, 1880, and December 31, 1880, 1685 claims for allowance and 352 bills for medical attendance were paid, the whole aggregating $41,503.14, and from December 31, 1880, to April 30, 1881, 699 claims for allowance and 182 bills for attendance of physicians were examined and paid, amounting to $25,077.48, making a total disbursement of one year of $66,580.62.

The second annual report of the Secretary, dated October 1, 1882, covered a period of twenty-one months, as the fiscal year of the association was changed so as to correspond with the fiscal year of the Baltimore and Ohio Company. This report shows a balance on hand December 31, 1880, of $47,040.12, and receipts from all sources $345,088.30, $322,038.20 of this amount being received from the members as premiums. The disbursements for the same period were $30 ,617.69, leaving a balance of $89,510.73, and six months' interest, $2500, making a balance September 30, 1882, of $92,010.73. But this amount does not represent the actual balance, for from it were to be deducted $40,473.60 for benefits due and not yet paid, and $21,424.46 insurance reserve, leaving a net balance of $30,112.67; and this balance, by the provisions of the constitution, is to be used "to reduce the next year's contributions or to increase the allowance for natural death or in promoting the interests of the association." By this report the number of members of the association is stated at 28,706, embracing "ninety-four per cent. of all employees in the service."

By these two reports the association has paid 91 claims of accidental death, amounting to $94,500; 189 claims of natural death,

amounting to $48,300; 3972 claims of disablement from injuries, amounting to $50,520.67; 2606 cases of physicians for services rendered in above cases, amounting to $20,096.29, and 9094 claims from disablements by sickness or injuries not received in discharge of duty, amounting to $127,689.39, making a total number of claims examined and allowed of 15,952, and a total amount paid of $341,106.35.

The affairs of the association are controlled by a committee of management, which includes the president of the Baltimore and Ohio Company and nine other members, four appointed by the company and five elected by the contributors. The immediate management is under the control of a secretary, who is elected by the committee and to whom all the business of the association is intrusted.

There are other benefits, such as half-fare in travelling, half-freights on building materials for homesteads, loans at 6 per cent. from the building fund, deposits at 4 per cent. in the saving fund, etc., which I omit from this account, since they do not properly belong in the relief department. There can be no better measure of the good done by such an organization than the amount of money it disburses annually; for this sum represents the burden which has been borne by the broad shoulders of the association, instead of being allowed to fall with crushing force upon the individuals. Judged by this standard, the organization just described has prevented a vast amount of suffering; and its report shows in a startling way, how great must be the hardships of employees who are not thus supported. It will be noticed that much the larger part of the relief granted, was not required as the result of accidents. Hence the extra-hazardous nature of the railroad business does not constitute the only ground, though it is an additional ground, for such an organization. It is a good thing in any business; and it is not charity, but insurance.

J. D. WEEKS, Pittsburgh, Pa.: The subject so thoroughly discussed in one of its phases, in the paper just read, has for some years provoked much thought and study, not only among employers and employed, but has demanded the attention of the ablest statesmen of the world. Bismarck's scheme for insuring the workingmen of all Germany; the Belgian "Caisses de Prévoyance;" the French "Secours," which also exist in Belgium; the British Employers' Liability Act, with the vast number of Friendly Societies which flourish in the United Kingdom, and the many voluntary societies in this country of a character somewhat similar to those described in the two papers just read, are all recognitions of the need of some method of

providing for the workman and his family in cases of disability or death, and are attempts to meet this recognized necessity. Whether these attempts are wise or not is a debatable question.

These schemes for insurance all assume, what is the fact, that many workmen cannot or do not out of their earnings provide for the inevitable hour when they are incapacitated for work. They are attempts to meet this inability or provide for this improvidence. One form these associations take, is the well-known beneficial organizations of this country, such as the "Odd Fellows," "Knights of Pythias," "Red Men," etc., and the Friendly Societies of England, of which the "Manchester Unity," the "Druids" and the "Foresters" may be taken as examples. These are secret organizations with a more or less elaborate ritual, intended to inculcate some moral lessons, but are at the same time sick- and accident-insurance societies, "dues" being exacted from the members, and "benefits" of a certain sum per week paid in the event of the disability of the members. These organizations have been remarkably successful in the great manufacturing centres of this country and England, especially among the workmen of the mills and mines of Pennsylvania, and of that section of England of which Manchester is the centre. They include men of all trades and positions in life.

The great trades-unions of this country and Great Britain, which differ from those just referred to in many respects, and especially in being confined to those engaged in the same trade, are also in many cases assurance societies. A large part of their payments are on account of sick, accident, or superannuation funds.

A second method of the development of this assurance principle is in State action. In many countries statutes have been enacted that are in effect assurance and relief laws. Among these are the laws establishing in Belgium the "Caisses de Prévoyance," and the Employers' Liability Act of England. The Belgian law is a distinct recognition by the State of the insufficiency of wages, and a deliberate intervention on its part to compel the manufacturers to supplement this insufficiency by additional payments, which form a fund out of which the disabled workman or his family is supported in whole or in part. Formerly both employers and employees contributed to this fund; now, only the former. It exists now only among the mines and iron-works, the glass-workers being so well paid that the necessity of interference on their behalf is not recognized. In 1880, 106,633 miners were affiliated with the several "caisses," 1,905,789

francs were expended, and the societies had 6,475,424 francs of a reserve fund.

The English Employers' Liability Act is intended to benefit the workmen by extending the liability of the employer in cases of the injury or death of the employee while engaged in his work. In connection with this act, various industries have made careful investigations as to the advisability of organizing societies for protecting individuals against excessive loss by distributing it over the whole trade. The iron-manufacturers' committee reported that the liability was so small that it was not advisable either to form an association or to insure in any of the accident associations that have been formed to take these risks. Other trades have taken different views.

The third form this insurance has assumed is that discussed in Mr. Harris' paper, one in which the employer and employed voluntarily unite to provide for the disability of the workmen. Quite a number of these Relief Societies exist in this country. The Baltimore and Ohio Railroad, and the Pittsburgh, Fort Wayne and Chicago Railroad have them. There have been several formed in the Pittsburgh mills, and in the mines of that neighborhood and in many establishments in various industries all over the country, they have been organized with most gratifying results.

The great difficulty in the way of the working of these associations, is the idea that workmen have that they are intended either as a charity, or to pay back, in some way, wages that have been unjustly withheld from them. They do not recognize the prevalent idea of wages in many cases as a just one. This view has interfered with the successful working of these Relief Associations, and will continue so to do. It will require the most prudent management to render them successful.

IMPROVEMENTS IN METHODS FOR PHYSICAL TESTS.

BY ARTHUR V. ABBOTT, C.E., NEW YORK CITY.

To rightly use materials, two kinds of knowledge are essential: first, the actual strength of the substance; and secondly, the forces to which, in the structure, it may be subjected. Nearly all of the data which we have at the present time have been obtained from the experiments made on the materials used in Europe, and by foreign investigators. The materials commonly used in this country, es-

pecially iron and steel, together with our processes of manufacture, are quite different from corresponding ones abroad, and the facts and figures obtained from English or German experiments are liable to be somewhat erroneous when applied here. It consequently becomes a necessity for us to make investigations for ourselves, and to determine, for the materials used here, the data whereby our structures may be made more secure and economical, and may inspire public confidence.

The first machines in this country were built by Maj. Wade and Capt. Rodman, and are still in use in the Washington Navy Yard and army building, New York City.

One of the early records gives an account of a small machine built by the late John A. Roebling, and located at his wire mill in Trenton, N. J. This machine consisted of a straining-apparatus connected with a scale-beam, and was used to test the qualities of the wire employed in the suspension-bridges built over the Niagara and the Ohio rivers.

A machine shortly subsequent to the above was employed by Murphy and Plympton at Trenton for the purpose of making tests of bridge I-bars. This is the first machine on record intended for making tests on full-sized members.

There then occurs quite a gap in the history of American practice; and the next move in the direction of further investigation was made by the United States Government, in 1874, by the appointment of a Board to make experiments on iron and steel and other metals, and an appropriation of $75,000 from Congress allowed for its use. The first action of the Board was to cause proposals to be issued for the building of an appropriate machine, and the result, to let to Mr. A. H. Emery, of Chicopee, Mass., a contract for such a machine, to be completed within five months from date. Unfortunately nothing had ever been constructed on the scale contemplated by the Board, and it was some four years before the machine was completed; but the result has been to give to the Government a machine which is in many respects without parallel, and, as the Watertown Arsenal Machine, is too well known to the members of the Institute to need further description here.

About two years ago, Messrs. Fairbanks & Co., having for some time been engaged in the manufacture of testing-machines, conceived the idea of locating in New York a bureau, or office, so arranged that engineers and constructors could be afforded an opportunity for making experiments and tests on any material, in any way, and to

give to America a laboratory that should speedily become to our country what the laboratory of Kirkaldy is to England. The improvements given in this paper are the result of the desire, on the part of Fairbanks & Co., so to arrange and supply their department of Tests and Experiments as to meet the wants of all investigators. These details, having been carried on under the supervision of the author, are now presented, hoping that they will be of interest to the Institute.

Five qualities are necessary to a successful testing-machine:

First. There must be a mechanism for producing stress up to the largest size of specimens that it is wished to test, and this mechanism must be sufficiently heavy and rigid to produce the stress without any distortion or undue straining of any of its parts.

Second. A contrivance for accurately estimating or registering the amount of stress applied to the piece under examination.

Third. A method for recording both the stress and its effects on the test-piece simultaneously.

Fourth. Such appliances to the testing-machine as shall enable the stress to be applied in any desired manner, and to any wished-for shape of the test-piece; and

Fifth. The ability of the machine itself to be easily and frequently tested, so that its record may hold the confidence of the community.

Many machines have, in one or more respects, failed to meet the above qualifications. Generally in the older machines there was considerable doubt as to the accuracy of the means employed to estimate the stress to which the specimen was subjected. In the hydraulic machines a gauge or other means was used for estimating the amount of pressure per square inch applied to the ram of the hydraulic press. In such machines the coefficient of friction is a constantly varying and uncertain quantity; so that an estimation of the pressure on the ram, however carefully made, is no accurate measure of the amount of stress to which the specimen itself is subjected. In machines so planned that the stress could be estimated in other ways than by the hydraulic gauge, the apparatus was so crude or subject to so many errors as to make the results obtained quite unreliable. Indeed, the Emery testing-machine was the only large machine at the time of its construction which was considered to be trustworthy.

In Fig. 1 an illustration of the machine now employed in the "Department of Tests and Experiments" is given, which it is hoped may be found to combine some improvements on foregoing

machines. From this illustration it will be seen that the machine stands on two cast-iron legs, which may be supported by any suitable foundation that is sufficiently strong to hold the weight of the structure. On these cast-iron legs there rests a framework of wrought-iron I-beams, so constructed as to give the entire structure an exceedingly solid and firm basis. On this frame-work of I-beams a system of levers is arranged in a manner very similar to that of ordinary scale-work, only proportioned to successfully withstand the severe stresses that come on it from the shocks and other use of the machine. These levers support a secondary framework, also constructed of I-beams, and carrying on its top four long columns. On the top of these columns stands a heavy casting from which are suspended two side-screws, sustaining the top cross-head of the testing-machine, to which one end of the specimen to be examined may be attached. These screws are simply used as a rapid and convenient means of adjustability, so that long or short specimens may be rapidly accommodated. It will be noticed that this entire system, namely, the adjusting screws and top cross-head, is supported entirely upon the upper frame-work of I-beams, forming the platform of the testing-machine. Beneath the top cross-head will be noticed a second cross-head, also supported on two screws, which are placed inside the adjusting screws previously alluded to. These screws carrying the lower cross-head extend downward through the platform and are attached to worm-gears firmly secured to the under side of the bottom framework. The worm-gears may be rotated in either direction at the pleasure of the operator, by means of the belt and a series of gears shown at the extreme right hand of the figure.

This system of worm-gears and screws forms the straining-mechanism of the machine, capable of applying any desired stress up to 200,000 pounds. Great care is taken in the construction of the machine that no part of this mechanism whatsoever shall touch or in any way come in contact with the platform of the machine. Consequently, no matter how much the lower cross-head be run up and down, no effect whatsoever will be produced on the platform, unless this cross-head be attached thereto by means of the specimen. It follows that all the stress produced by the cross-head on the platform must necessarily pass through the specimen, and only this amount and no other can be estimated on the weighing-beam of the machine. A part of the scale-system previously referred to may be seen on the front of the figure; the end of one of the large levers extending under the platform, and two small ones carrying the

stress from the end of this lever to the beam, and designed to increase the multiplication of the machine and reduce the amount brought to the beam itself. Over the larger one of these levers are four small columns extending upwards and supporting on their top a hand-wheel and ratchet. This is an auxiliary testing-machine, so planned that the one piece of apparatus includes two machines—one large one for making tests of full-sized specimens, having a capacity of 200,000 pounds, reading to 10 pounds, and accommodating specimens up to 10 feet of length; the other having a capacity of 10,000 pounds, reading to half a pound, and accommodating specimens up to 2 feet of length. It will thus be seen that this testing-machine is a sort of *multum in parvo*, combining the capacity for making large and small tests.

Leaving the perspective view, let us pass to Figs. 2 and 3, the longitudinal and transverse sections taken directly from the drawings of the testing-machine. Here will be seen standing on the floor the cast-iron legs a a', supporting the framework of I-beams b, b, b, b. On these I-beams there stand at each end two solid cast-iron blocks that support, hanging by two loops, the main levers, c, c. On the center pivot of these levers stand two castings, b'', b'', that carry the foundation I-beams, b', b', of the platform. On the top of these beams is arranged a series of eight smaller beams, c', c', that carry the longitudinal beams, A, A, for supporting the anvil blocks, 40; also the beams c' c' sustain the columns j, j, carrying the top castings with the adjusting screws, h, h. The other ends of the main levers, c, c, are attached by means of their extreme pivots and loops to the central levers, e, e'. These levers carry the stress imparted to the platform to the end-lever, f, whence it is carried to the beam, where it may be estimated by sliding the poises to and fro until a balance is obtained. It will also be noticed that between the lower I-beams of the frame there is placed a heavy casting, k''. This casting supports the main driving screws, k, to which the lower cross-head, m, is attached. These screws are kept in their place by a small collar placed on the top of the I-beams, and by a worm-gear and a heavy nut on the under side of the casting, k''. These worm-gears are cut respectively right and left-handed, and correspond with similar threads on the screws themselves. The object of cutting the screws with different threads is to cause them to rotate in opposite directions, and so to neutralize all tendency to twist or turn on the part of the cross-head, due to the large amount of friction caused by the screws under heavy

pressures. These worm-gears may be rotated by means of the worms and the lower shaft, l. This lower shaft is connected at the left hand of the machine with a series of gears and a tight or loose pully, driven by a belt, l^3 (Fig. 3). The object of these gears is to communicate different speeds of rotation to the driving shaft, l, so that the testing-machine may be driven at varying speeds at the pleasure of the operator, and that the cross-head may be moved up and down at such rates of speed as his judgment may deem the best for the specimen under examination. At the right hand of these gears may be seen a set of reversing-gears very similar to those employed in the ordinary lathe, so that at pleasure the direction of the motion of the cross-head may be changed from up to down, or vice versa. Perhaps the action of the machine may be now fully understood by supposing a test-piece in tension. The piece is first secured in the top cross-head, B, by means of the wedges placed therein. The other end is then secured to the lower cross-head, C, thus forming the only connection between the platform and driving-mechanism. As fast as the screws are turned, stress is exerted on the specimen which is communicated to the platform, and may be weighed by means of the beam at the left hand. It will thus be seen that two qualifications have been here fulfilled. In the first place the straining-mechanism is sufficiently firm and rigid to produce all the stress that the machine is intended to exert, without any straining or undue distortion of its parts; and second, that only the stress to which the specimen is subjected can by any possibility come upon the platform.

A third qualification may be here mentioned, as being peculiar to this form of testing-machine, and that is the facility by which at any time the machine itself can be tested.

Referring again for a moment to the perspective view, it may be seen that the platform of the machine occupies considerable space, being some ten feet long by six feet in width. Now as this platform is supported simply and solely on the levers of the scale, any weight which is placed on it must be immediately felt by the beam itself; consequently, in order to test the machine all that is necessary is to pile on the platform either a series of standard test-weights, or a previously weighed quantity of any material. If, for example, 20,000 pounds of dead weight be placed on the platform, and by moving the poise out on the beam it is found that the beam balances at a corresponding figure, namely, 20,000 pounds, there is an ocular demonstration that a certain number of pounds of dead weight produces a corresponding reading on the beam. Consequently, when

the specimen is placed between the jaws of the testing-machine, and it is remembered that the only stress exerted by the screws on the platform is transmitted through the piece, and 20,000 pounds is indicated by the beam, it is obvious that the specimen must be undergoing a stress of a corresponding amount. It may be stated that in the process of manufacture of all such machines each of the levers which enter into the construction is scaled separately; that is to say, when the lever is made it is hung on its fulcrum, and weights in the proper ratio are hung on each of the exterior pivots. The edges of these pivots are then moved to and fro slightly until the loads on each exactly balance each other. The lever is then supposed to be correct, and after the entire machine is set up weights are piled on the platform, and the beam and the poises adjusted until every mark on the beam is indicated by a corresponding amount of dead weight on the platform, so that, as will be readily seen, the machine is adjusted to itself and all coefficients of friction whatsoever are thereby eliminated.

Of course it may be urged that in time the edges of the pivots may become dulled and the coefficients increased. This is true, but in fact, so far as is known, no machine has been constructed which is not susceptible to some wear in the course of time. Simply as a matter of history it may be stated that the machine now brought to your notice has been in constant and severe use for nearly two years. An experiment tried a few days ago revealed the following facts: When the machine was unloaded a weight of three-fourths of a pound on the platform caused the beam to promptly rise and stand at the top of the surrounding guard. As the least reading on the poise indicates a weight of ten pounds in the machine, an error of three-fourths of a pound, necessary to turn the beam, may be considered so small as hardly to be worthy of notice. A test-piece was introduced into the machine and a strain of 100,000 pounds placed on the platform, and a weight of six pounds was then added to the platform, which again caused the beam to move; consequently, it is obvious that a load of 60 per cent. of the smallest reading of the poise was sufficient to cause a visible motion of the beam, even under a heavy load in the machine.

The following may be quoted from the report of government engineers detailed to inspect a machine similar to this built a year ago for the Navy Yard in Washington: "We also tested the machine for sensibility both before and after subjecting it to the maximum strain, without finding any difference. It responds promptly to a

weight of one and one-fourth pounds, which may be taken to be its maximum error."

The preceding example is the way in which the machine is most commonly called to act, namely, of tension. It is, however, equally adapted to making experiments in compression, transverse strains, sheering, bulging, punching, and torsion.

In Fig. 2 a skeleton specimen will be seen, calling the capacity for transverse tests into play. The transverse blocks 40 and 40 are carried to and fro on the platform by means of screws 42, so that they may be adjusted with reference to the centre of the testing-machine at the pleasure of the operator. Under the cross-head C, will be observed a small triangular block which is depressed with the motion of the cross-head, and applies the stress to the specimen that is supported on the hardened steel blocks 44. These hardened steel blocks are semi-cylindrical, and rest in concavities cut in the top of the supports 40. The object of these blocks is to permit the piece to freely deflect under the application of the central load, while at the same time the original span used in the experiment is rigidly preserved, as the blocks rotate about their centres, maintaining a constant distance from each other. By removing the triangular-shaped jaw from the under side of the cross-head and substituting in its place a flat iron plate, and placing on the I-beams underneath a similar plate, the machine may be easily and readily arranged for compression-tests. In these three examples it is plain that the entire stress to which the specimen is exposed is transmitted through the piece to the platform. In the case of the tension-specimen, a downward pull on the piece is transmitted along the adjusting-screws to the columns and thence downward on to the platform. In the transverse test, the downward pressure of the cross-head is transmitted to the supporting blocks, thence to the I-beam A A, and then on to the platform, and in the case of the compression test a similar result is obtained by transmitting the pressure directly through the piece to the I-beams A, A, so that in all conditions and under all forms of stress to which the material can be exposed, the test-piece forms the only connection between the weighing apparatus and the mechanism employed in producing the stress on the piece.

Nearly all the results of tests are so largely dependent on the skill and the personal equation of the operator manipulating the testing-machine that very naturally much hesitation has been felt in accepting as conclusive the results so obtained. It has been the aim of the author in the design of the present machine so to arrange its

construction that as far as is mechanically possible the machine itself should do its own work, thereby eliminating from the result all personal equation on the part of the operator. One of the greatest obstacles to making accurate tests has been the difficulty of making the axis of stress of the machine coincident with the axis of the specimen. In making experiments on wrought iron or steel, or upon other materials which have a more or less ductile character, this objection is not a serious one, as it introduces but a slight error in the results. In experiments on cast-iron, cast-steel, or other materials of an essentially brittle character, the slightest cross stress vitiates the results by introducing stresses into the test-piece which are entirely contrary to those desired, and which produce effects not to be calculated.

By referring to Fig. 3, a device for enabling the machine automatically to centre the test-piece may be understood. The top and the bottom cross-head have in their centres a large spherical concavity. This concavity contains a segment of a sphere into which the wedges for gripping the test-piece are placed. The spherical segment is made of steel, turned and polished as smoothly as machine-work can make it, and the concavity on the cross-head is lined with the best anti-friction Babbit metal, reducing as low as possible the coefficient of friction between the sphere and its socket. Let it be supposed that the piece is placed in the machine eccentrically. The first operation, as soon as the screws are turned and the lower cross-head commences to descend, is to produce a slight stress on the piece. This stress comes on the spherical segments eccentrically, and the tendency is immediately to swing the segments in their sockets and cause the axis of stress in the machine to coincide with the axis of the test-piece. The spherical segments in question weigh about 200 pounds. They are, however, carefully supported on India rubber springs so as to eliminate, as far as possible, the weight of the segment from the friction in its socket. But suppose, under the most unfavorable circumstances, that the whole weight of the segment does come on the joint, the coefficient of friction is not over two per cent.; consequently, a maximum cross-strain of four pounds on the test-piece will cause the segment to swing and to adjust itself to the axis of stress through the piece. As this weight of four pounds is less than half the reading of the poise, it may be assumed to produce no sensible effect on the piece to be examined. Most of the testing machines now in use require a careful preparation of the test-piece previous to an examination. If, for example, it is wished

to ascertain the strength of an I-beam or a channel, it is necessary to send the shape to the machine-shop and plane out a piece. This requires much time and quite an outlay of expense. The piece is then sent to the testing-machine and broken, causing an additional expense, and after the result is accomplished, what is obtained? Simply the result of a piece cut from the shape which may or may not give a fair knowledge of the actual strength of the member in question. What is wanted to be known at the present time is not the strength of a carefully prepared test-piece, broken under special circumstances, but of the actual bar just as it comes from the rolls in the mill itself.

Engineers want to know the strength of an I-beam, the tenacity of a channel, the cohesive strength of an angle, the compressive resistance of a post, actually, of the pieces themselves, and not a calculated result to be obtained by cutting from the shapes in question a test-piece and figuring the possible result of the whole shape. It has been the aim of the author so to arrange the testing-machine that full-sized shapes of any description could be placed therein and broken without any preparation whatever. The advantages of this are very obvious, for it not only saves the cost and time necessary to prepare the test-piece, but also gives the desired knowledge of the strength of the full-sized shape. A well-known example of the desirability of this may be quoted in the experience of Capt. Eads in the St. Louis bridge. Test-pieces of the steel bolts stood in the testing-machines stress of 90,000 pounds to the square inch. Some circumstance caused Capt. Eads to suspect that the bolts themselves would not reach that quantity, and after building a testing-machine especially for the purpose, it was found that the bolt broke at something like 40,000 pounds per square inch. If the St. Louis bridge had been built on the 90,000 pounds supposition, there would have been one more instance in the long catalogue of engineering disasters.

The spherical segments in the cross-heads of our testing-machine have four sides inclined at an angle of about twelve degrees to the axis of the machine. Two of these sides are curved and two are straight. By using a number of wedges with sides correspondingly curved or straight, any piece of whatsoever section may be completely surrounded by the wedges and gripped on all sides so that a channel, an angle, an I-beam, a tee, or a star, or, indeed, any of the shapes now rolled in the mills, may be placed in the machine and broken in full size.

In making the designs for this testing-machine, much time and labor has been spent to accomplish the third qualification introduced in the beginning of this paper, as necessary to a testing-machine, namely, the power of autographically recording at each instant of time during the experiment the amount of stress and the strain produced thereby on the specimen. To the best of the author's knowledge, Professor Thurston, of the Stevens Institute, was the first to originate the idea of making a testing-machine in such a manner as to record graphically on a sheet of paper the result of the test. In 1876, at the Centennial Exhibition, Prof. Thurston exhibited a machine designed to make tests in torsion and to record the action thereof. As a matter of history it may be stated that while engaged in examining material for the East River bridge, in 1877, the author designed and built the first machine to autographically record results of the experiments in other stresses than that of torsion. While this machine, being the first of its kind, was necessarily crude and imperfect, it gave for some years very satisfactory results, and is still in use by the bridge company.

Referring to Fig. 3 (the cross-section of the machine), it will be seen that a pole of the battery, G, is attached to the top of the adjusting screws *h h*. These screws are carefully insulated from the rest of the machine, all standing on a rubber base and passing through a rubber bushing held in the interior of the top casting; consequently, these screws with their corresponding cross-head are electrically insulated from the rest of the testing-machine, and, being joined to one pole of the battery, form the only means by which the current can flow into the machine itself.

As soon as the test-piece is placed in the top cross-head it becomes thereby connected with the battery. On the lower end of this specimen may be seen a small clamp carrying an electro-magnet. One end of the wire of this magnet is in connection with the specimen, while the other end of the wire is joined to a little binding screw on top, to which the other pole of the battery is attached, so that the current actuating this magnet flows from the test-piece under examination. It will be also seen that the magnetic clutch K for holding the driving belt of the tight pulley is also included in this part of the battery circuit. As long as the specimen remains intact, the current flows from the battery, excites the two magnets and attracts their armatures. When the rupture of the test-piece occurs, the current is at the same instant broken, the magnets are demagnetized, the clutch is released, the belt slides by means of the coun-

terpoise weight to the loose pulley, and the testing-machine stops. On the top of the specimen nearest to the upper cross-head is attached a second clamp carrying a small sheave or pulley. Around this pulley, parallel to the specimen and attached to the armature of the lower clamp-magnet, passes a flexible steel tape, *y*.

Referring to Fig. 4, an enlarged view of the specimen and clamp with its magnet may be seen. Here it will be noticed that the tape, after passing along the specimen, runs down to a pencil or stylographic pen, that is carried on a sliding track, placed over a metal cylinder, carrying a sheet of cross-section paper. It is at once obvious that as fast as the specimen elongates under the action of the stress, the pencil is drawn along the ways of the cylinder, parallel to its axis. This axis (the axis of X of analytical geometry) is assumed to be the axis of elongation. Inasmuch as the cross-section of the tape is very large in comparison with the friction of the pencil carriage and the supporting pulleys, the tape itself is subjected to comparatively little stress, and is always kept tight and in its place by means of the counterpoise weight y'; consequently every deformation of the specimen is accurately recorded on the cross-section paper by a corresponding motion to and fro of the pencil. In actual practice it may be said that the record on the cross-section paper corresponds within $\frac{1}{100}$ of an inch to the elongation of the specimen, and this for ordinary experimental work is sufficiently near. An enlarged view of the clamp with its magnet may be seen in the figure. It will be noticed that the clamp is supplied with a spring and screw *w*. The screw is employed for securing the clamp to the specimen, and the spring serves to take up any reduction in area caused by the drawing down of the piece, and to constantly keep the clamp tightly secured in its place. Next to the magnet, the side of the clamp is supplied with two edges, one rounded and one sharp; the sharp edge slightly indents itself into the specimen and secures the clamp rigidly into its place, and forms a zero-mark, from which the percentage of stretch may be readily calculated, while the rounded edge prevents the clamp from rocking, and at the same time allows the piece to stretch freely. The sharp edges of both are placed next to the jaws of the cross-head. Consequently it is very rare that a specimen can break outside of these knife-edges, which form data-marks of reference from which the per cent. of elongation may be recorded.

The autographical record of the deformation of the specimen is by this means made plain. It now simply becomes necessary to

record at the same time the stress producing the deformation. Turning to Fig. 5, an enlarged view of the beam with the registering cylinder may be obtained. From this illustration it is perceived that the beam is composed of two parts—a top bar and a lower bar, each carrying its appropriate poise. The large poise is ten times as heavy as the small one; consequently the small one must move ten times as far as the large one to produce a corresponding effect on the scale. The entire travel of the small poise is equivalent to a weight of 10,000 pounds in the testing-machine, while the entire travel of the large one is equivalent to the entire capacity of 200,000 pounds. On the end of the beam will be seen two mercury cups, 15 and 13. The skeleton view of the beam with its apparatus, shown in Fig. 6, may perhaps render this a little more obvious, and should be consulted at this time. (In this figure the mercury cups are marked 16 and 17.) From the lower cross-head of the testing-machine, which it will be recollected is connected with the specimen carrying the current, the electric force flows into the butt of the beam. The two mercury cups at the end of the beam are so arranged that when the beam is in the centre, neither cup is included in the electric circuit, which is consequently broken. If the force on the platform increases, the beam rises and the upper cup is brought into the circuit, and the electric current begins to flow. Should the weight in the testing-machine decrease, the beam falls into the lower cup, and the electric circuit is also completed through that one by the drop of the beam. It will be seen, in Fig. 6, that the lower poise on the beam is connected by means of the steel tape q with a little countershaft r.

This countershaft is joined by an open and crossed belt and two magnetic clutches t^4 and t^5. These clutches are placed upon the shaft that is driven by the clock-work t. When the beam rises, the magnetic clutch t^4 is excited by the completion of the circuit through the mercury cup 16. As a consequence, the small poise is immediately drawn out along the beam tending to rebalance it. Should the motion of the poise equal the weight on the platform, the beam then sinks to the centre, the circuit is broken, and the poise stands still. If for any cause the force on the platform decreases, the beam drops into the lower cup, the magnetic clutch t^5 is excited, the cross-belt p^2 begins to move, and the poise is moved backwards on the beam, tending again to rebalance it.

Returning to Fig. 5, a switch will be seen at 21, so placed that when the small poise reaches the maximum extent of its travel it

strikes against this switch and automatically closes the electric circuit, through the magnet O^3. The effect of this circuit is to excite the magnet, release the large poise g^4, and cause it to move out a distance which is exactly equivalent to the total travel of the small poise on the lower beam. Instantaneously with the motion of the large poise, the beam, superweighted, drops, closing the circuit in the lower cup, and returns the small poise to the butt of the beam. It is thus plain that the rise and fall of the beam absolutely controls the motion of the poises, and the beams form an automatic shunt for so circulating the electric current as to cause the poises to move to and fro. This motion of the beam is entirely dependent upon the pressure exerted on the platform, so that it is obvious that the piece being placed in the testing-machine, the weighing may be done by the machine itself automatically in a way far more sensitive and accurate than is possible to accomplish by any hand-labor, however skilled. In order to accomplish the registration of the motion of the poises, which is all that is necessary to record the stress on the specimen, the cylinder previously mentioned is magnetically connected with the shaft r, so that as fast as the poises travel out, a worm-gear, connected with a magnet on the cylinder, causes the cylinder to revolve circumferentially, thus making the axis of Y the axis of stress. The motion of the pencil, as previously has been shown, records the deformation of the specimen; while the motion of the cylinder, as is now plain, records the motion of the poises. By so proportioning the pitch of the worm-gear, that an inch on the circumference of the cylinder corresponds to a definite number of pounds on the testing-machine, it becomes an easy matter to read from the motion of the cylinder the amount of force which has been applied to the specimen; consequently the curved line that is marked on the cross-section paper, by the combined motion of the pencil under the influence of the tape and of the cylinder, gives a record whose abscissæ and ordinates are measures respectively of the stress to which the piece is subjected and the resulting strain. As soon as the piece breaks, the current which actuates both the motion of the testing-machine, the motion of the tape and the motion of the cylinder, is ruptured. The machine stops, the beam falls, the poise stands still, and the pencil comes to rest, leaving the record on the cross-section paper for any future inspection.

The preceding method of obtaining autographic diagrams possesses many advantages for adapting it to testing-machines that are to be built especially compact. There is, however, another method of ob-

taining the same results whereby the registering cylinder may be located at any distance from the testing-machine. Figs. 7 and 8 are two photo-engravings from the beam and registering cylinder employed in the "Department of Tests and Experiments." In Fig. 7 it will be seen that the beam consists of a single bar, suspended on a stand at one end and inclosed in a guard at the other, while on this beam there rests a semicircular brass box, forming the poise. Along the top of the beam there is cut an exceedingly fine rack, and the motion of the poise is obtained by a pinion placed inside the box and gearing into this rack. At the end of the beam may be seen the mercury cups alluded to in the former method for making the electrical connection as the beam rises and falls. The operation of this piece of apparatus is substantially as follows: The clock-work motor for driving the poises to and fro on the beam is connected with the mercury cups by means of some brass strips placed in the rear of the steel bar forming the beam. These strips are connected with two electro-magnets on the inside of the poise; consequently, when the beam rises or falls, one or the other of the magnets is excited, the corresponding train of clock-work thrown into action, and the poise quietly rolls to and fro until a balance is re-established. This part of the apparatus—that is, the accomplishment of the motion of the poise to and fro on the beam—is exceedingly simple, the knotty part of the problem being to correlate the motion of the poise with the motion of the cylinder exactly, so that in the given travel of the poise along the beam the cylinder may move a corresponding quantity.

Of course the ratio between the two movements is simply a matter of proportioning so as to accommodate an ordinary cross-section sheet to the circumference of the cylinder, but it will be readily seen that an exact and constant ratio is a very important point.

To solve this problem was to accomplish the solution of one analogous to that presented by the autographic telegraph, the electric clock, and similar pieces of mechanism; but with some peculiar features arising only in this special instance. To go a little more into the details of the poise, there are inside of the brass box two large wheels, about eight inches in diameter. The wheel placed on the front of the poise is graduated with a series of numbers. The pinion carrying the poise along on the beam is an inch in circumference, and, consequently, a single revolution of the pinion carries the poise one inch along the beam. The wheels are secured directly to the pinion shaft, so that there can be no backlash between them.

and being eight inches in diameter one revolution of the pinion causes these wheels to travel about twenty-five inches of circumference. In the testing-machine in question a motion of one inch along the beam corresponds to a weight of 4000 pounds in the testing-machine. The front wheel is graduated, being subdivided into 400 parts; each of these parts corresponds to ten pounds in the testing-machine. The rear wheel of the poise is constructed in precisely the same manner as the front wheel, excepting that the marks on the dial are replaced by little strips of India rubber, so that the wheel presents a series of teeth, alternately made of India rubber and of brass. On this wheel there presses a brass commutator-strip so arranged as to include the cylinder in the electrical circuit. As soon as the poise commences to move along the beam this wheel with its India rubber spaces commences to turn under its commutator-strip, and with every passage of a tooth under the strip a flash of electric force passes into the cylinder. Turning to Fig. 9 a detailed drawing may be seen, taken directly from the cylinder. Here it may be observed that inside of the cylinder are two toothed wheels. Each of these wheels is mounted on the central shaft, and is capable of being ratcheted round by means of a little lever-arm and pawl that is operated by a magnet placed directly under each of the wheels. One of these wheels is intended to drive the cylinder in one direction, and the other in a contrary. One electro-magnet is connected with a mercury cup on the bottom of the beam, and the other with a mercury cup on the top. As a consequence, as soon as the beam makes connection with either cup and the poise commences to travel, the corresponding electro-magnet is excited, the armature acts and commences to ratchet the wheel around, and, by means of the connecting gears seen at the extreme right hand, move the cylinder in one way or the other. It will thus be seen that if the gears in the cylinder are properly proportioned and accurately cut, and if the magnet makes a stroke for every tooth on the insulated poise-wheel, the cylinder will be moved through an amount that is exactly commensurate with the motion of the poise itself. At first sight it would seem that so accurate an arrangement were almost impossible to construct; so it is with all of our machines of precision, yet nobody despises a Swiss watch or a micrometer gauge on account of the possible difficulties in manufacture. In the case in question it has been found that an entire revolution of the cylinder may be made to correspond with the complete travel of the poise along the beam within a possible error of one-hundredth of an inch. Now, if we allow the strip of cross-section

paper to be forty inches long and give a stress-reading of 4000 pounds to the inch, one-hundredth of an inch corresponds to forty pounds. Inasmuch as this is the smallest practical reading to be made on cross-section paper, and as it is four times as large as the smallest reading of the poise, it will be seen that this error of one-hundredth of an inch in the entire travel of the cylinder is too small to be taken into any practical account. On the top of the cylinder there may be seen a track carrying a carriage and pencil, connected with the specimen by means of a steel tape in precisely a similar way to that used in the method previously described. Between the motion of the cylinder and the poise, it will be noticed that there only exists the same connection as occurs between any two telegraph stations; consequently, if it be desired, the machine may be placed in New York and the registering cylinder in Cincinnati, and the two work absolutely in harmony with each other; or should it ever be deemed expedient, the cylinder may be inclosed or locked up in a way to be absolutely exterior to any control on the part of the operator manipulating the testing-machine.

An old proverb has said that "the proof of the pudding is in the eating," and now in Fig. 10 may be seen a photo-engraving made from a sheet of cross-section paper, on which, by means of the last method in question, have been drawn a half-dozen curves corresponding to as many test-pieces. In this particular sheet, in order to economize space, the vertical scale along the axis of Y or axis of stress has been made 10,000 pounds to the linear inch, while the distances along the axis of X or axis of stretch (for all the tests here recorded were made in tension), are the normal stretches of the pieces under examination.

The cross-section paper has been ruled in feet and decimals of a foot, and each of the specimens were one foot between the stretch-clamps; consequently, the actual stretch of the specimen may be at once read in per cent. of length. The lower half of the sheet contains three steel-curves, which, it will be readily seen, bear to each other a strong family resemblance. In the first place, the curve commences with a line slightly inclined to the axis of stress at a constant tangent, or one which may be expressed by the equation, $y = ax$. As soon as the elastic limit is reached, a sudden point of inflection occurs, the tangent becoming nearly or quite parallel to the axis of X. Very soon, however, a second point of inflection occurs, the tangent returns nearly or quite to its former inclination, and the curve takes on a general parabola form. In fact, nearly

all steel-curves are cubic parabolas of one form or another. The steel-curves, as well as that given by the specimen of Ulster iron, may be taken to be typical forms or curves, to be obtained from a material which is nearly or quite homogeneous. Here it will be seen that the lines are quite true and regular, and that the curve proceeds over the cross-section paper without any special irregularities, until the maximum stress is reached shortly before the specimen breaks. The stress then commences to decrease, owing to the rapid reduction of area of the piece under the action of the machine, and with the reduction of the stress the curve drops and returns toward the axis of X, until very shortly the specimen is ruptured, and the apparatus comes to a standstill. The other three curves, given by a piece of boiler-plate and of two specimens of muckbar, are very good examples of the value of the autographic method of giving a practical indication of the molecular construction of the material to be experimented on. As is well known, both boiler-plate and muckbar are decidedly non-homogeneous, and, as a result, we have curves here that are exceedingly irregular, especially after passing the elastic limit. While they bear a general resemblance to the previous ones, they are full of points of inflection, turning and twisting about, and giving one an idea that the specimen consisted of a bundle of threads or fibres, which gradually parted under the action of the stress, giving anything but constant and uniform action. For a general record of the test, it is believed that the autographic method is superior to anything else. At the same time it is not sufficiently refined for accurate investigation into the limit and modulus of the elasticity, inasmuch as it is impossible to read on the cross-section paper nearer than about $\frac{1}{100}$th of an inch, and inasmuch as any arrangement to magnify the stretch up to the elastic limit, would give the elongation after passing that point in such dimensions as would carry it far beyond the capacity of any sheet of cross-section paper now to be obtained in the market.

The autographic diagram will give the limit within a thousand pounds to the square inch, and the modulus within a hundred thousand pounds. Yet, for many purposes, it is very desirable to know these quantities and obtain a nearer approximation to these quantities, and in Fig. 10 may be seen an illustration of a piece of apparatus, devised by Colonel William H. Payne of the East River Bridge, and used by him there in experiments on the steel to be used in the trusses. It will be seen that the apparatus consists of two steel bars A and B, so arranged as to slide parallel to each other.

At the ends, each bar is supplied with a knife-edge F, held in a solid piece of brass M, which may be adjusted at any point on the bar. By means of these knife-edges the whole apparatus may be clamped to the specimen by use of the springs G on the bar A, a small steel projection O, bears against one of the knife-edges of a multiplying lever C, and the other end of this lever comes in contact with the supplementary vernier and scale D and E. Now as the piece under examination elongates, the bars move by each other, the multiplying lever C turns on its fulcrum, pushing the vernier D outwards along its scale. Thus it is obvious that the whole apparatus, after being placed on the specimen, works entirely without intervention from the operator. In the case of micrometer-screws, it becomes a pretty difficult matter for the same person to make readings twice alike, on account of the varying coefficient of friction and of the varying personal equation. And, again, the operation of making readings with micrometer-screws is exceedingly slow, and should, as in the case of hydraulic machines, the pressure have any tendency to relax, it is almost impossible to obtain a correct reading, whereas, in the gauge in question, the reading may be made as fast as the eye can gauge the coincidents between the vernier and the scale. While making many thousands of steel tests for the East River Bridge at the works of the Cambria Iron Company, the author used this gauge, and employing one man to place the weights on the beam, was accustomed to sit where the vernier of the stretch-gauge could be seen, and at the moment that the beam raised, to catch the reading of the scale. Then, the entire operation of making a test on a bar a foot long and an inch square, including the making of some twenty or thirty readings, did not occupy more than eight to ten minutes, which is a speed never to be attained by any arrangement of micrometer-screws. By means of the extension-rod and clamp L and M, the sliding bars of this piece of apparatus may be extended to any desired length, and by this means it becomes an exceedingly valuable instrument in the investigation of the strains which occur in structures already existing, such as bridges, roofs, and the like. As a case in point, may be mentioned an examination by the author at the opening and test of the new cantilever bridge at Niagara. Two gauges were employed at the test of the cantilever, vernier A being secured to a tie-bar on the truss extending over one panel, and vernier B attached to a bar extending over two panels from the anchorage end of the cantilever on the American side. Vernier A extended over a distance of 4.75 feet, and

vernier B over a distance of 5 feet on the bars. Readings were taken at the various points at which the loading trains came to a stand, and gave the extensions produced by a quiescent load. During the movement of the trains, the verniers fluttered a little, showing that even at slight speed there is a sensible effect from shock, and, as the loaded trains moved off on the American side, there was a negative reading of about $\frac{25}{1000000}$th of a foot, showing that the bar was undergoing a slight compression.

The following are the readings of the verniers, reduced to a length of one foot of bar:

Train at the Canadian abutment, vernier A, ...	$\frac{10}{100000}$ of a foot.
" " " " B, ...	$\frac{12}{100000}$ "
Train at Canadian tower, vernier A, ...	$\frac{74}{100000}$ "
" " " B, ...	$\frac{72}{100000}$ "
Train at Canadian end of centre span, vernier A, . .	$\frac{106}{100000}$ "
" " " " " B, . .	$\frac{132}{100000}$ "
Train at American abutment, giving the maximum strains in the law under examination, vernier A, ...	$\frac{165}{100000}$ "
" " " " B, ...	$\frac{212}{100000}$ "
Centre span, entirely loaded, vernier A, ...	$\frac{106}{100000}$ "
" " " " B, ...	$\frac{102}{100000}$ "

Bridge unloaded, verniers returned to zero, assuming the modulous of elasticity of the I-beams, the following stresses per square inch are obtained from the preceding measurements:

Bar extending over two panels, ...	6,780 pounds.
Bar extending over one panel, ...	5,280 pounds.

According to the strain obtained from the bridge engineers, the maximum load in the long bar should be 7,190 pounds, thus giving a difference of only 400 pounds between the calculated load and the load obtained by these gauge measurements.

In conclusion, a word as to the practical accuracy of the lever testing-machine may not be out of place. The machine under consideration has been subjected to severe use for a period of nearly two years, during which time its sensitiveness, even when loaded, has not decreased to the least reading on the poise. From this, and from long practice in similar scale-work, it may be safely stated that a testing-machine, with proper care, may have an exceedingly long life. The attainment of absolute accuracy in any department of investigation, would, if it were possible, be an extremely desirable result, yet even our best experiments are simply close approximations to the truth, and I think it will be granted that it is desirable to make all improvements commensurate towards an absolute standard

of accuracy. It is of no importance to carry the accuracy of the weight-beam beyond the possibility of the measurement of the bar. Suppose the tests most frequently made, to be those on specimens having about a square inch of cross-section. In a piece of iron of this size, an error of measurement of $\frac{1}{1000}$th of a square inch of cross-section, corresponds to a possible inaccuracy in the ultimate calculated stress of the bar of 50 pounds, while the corresponding quantity in the steel bar corresponds to about 70 to 90 pounds.

There are very few lathes in the country in which it is possible to turn a bar so exactly that it shall be perfectly round, and that there shall be no variation from one end to the other of more than $\frac{1}{1000}$th of a square inch. Now if it be impossible to measure the size of test-bars to within an error of 50 to 100 pounds in the testing-machine, is it of any importance to refine the machine beyond this reading? In the lever system of testing-machine, it is perfectly possible to obtain a machine which shall uniformly and constantly give readings which shall not have a greater variation than from 5 to 20 pounds; and if bars can only be measured to 50 to 100 pounds, would it not be wiser to spend money in refining measuring instruments, rather than in the refining of the testing-machine?

When tests are made on full-sized members, or on bars direct from the rolls, carrying with them the scale and the other imperfections from the mill, the possibility of measuring to a thousandth of a square inch becomes absurd, and even three or four hundredths of a square inch is the nearest approximation that can be made; for example, in making a test on an ordinary I-bar of, say, 5 or 6 inches of cross section, it is certain that the bar was anything but an absolutely uniform section from end to end, and how long, may it be asked, would it take to measure that bar so that the least cross-section could be obtained for the record? And again, in actual experience it has been frequently found, that, having obtained what is supposed to be the least cross-section, the test-piece may break in a totally different place. I think it will be conceded, without doubt, that practical engineers care very little for test-records beyond the hundredths-place of figures, and what is wanted at the present time, is not so much the machines constructed on a theoretical refinement of accuracy, but a large number of practical machines, so that one may be located in every iron-works in the country, and money enough to carry on the experiments and to obtain from these machines a practical knowledge of what America's constructive materials really are.

A NEW MINERAL.

BY NELSON W. PERRY, E.M., CINCINNATI, O.

Some months ago a gentleman gave me a handful of minerals which he had collected in an *arroyo*, or dry stream-bed, that ran through the town of Ramos, State of San Luis Potosi, Mexico, as a sample of the class of ore that might be expected in the mines of that section. I was, however, familiar with those mines and their ores, and cast the pebbles aside as of no interest. I afterwards returned to Mexico and took charge of two groups of mines, one in the State of Zacatecas, and the other in the town of Ramos, State of San Luis Potosi. While I was thus engaged, it was a very frequent occurrence for parties to bring me specimens of rock, ores, etc., for my opinion on them; and one day a man brought me a half-dozen or more small pieces of a very black shiny mineral, desiring to know what it was. I did not recognize it, and desired him to give me the specimens for analysis, which he promised to do in a day or two. He never did give them to me, for he lost them; but he said there were plenty more where these came from—at Ramos—and he could get them at any time for me. I thought no more of the matter until after my return to this country, when, one day, in looking over some of my old "trash," I came across the specimens at first referred to as having been cast aside so carelessly. I noticed two distinct minerals among the pebbles: one being erubescite or tetrahedrite, the predominating mineral of the mines of Ramos, and the other a hard black shining mineral, the same that I had wished to analyze in Mexico. On testing for hardness I was surprised that it scratched topaz with some degree of ease, thus placing it above 8 in the scale of hardness. Trying it with a corundum, I sometimes succeeded in scratching it, but at other times it would scratch the corundum, and at still other times neither would produce the slightest effect on the other. Crystallized topaz would be ground to a powder in attempting to scratch the black mineral, without abrading it in the slightest. It must, therefore, be placed at 9 in the scale of hardness.

It is of the deepest opaque black, not unlike pitch-blende in ap-

pearance; but the edges, of extremely thin splinters, show a slight translucency, and by transmitted light appear of a dirty greenish-brown. Also, these same edges are, with difficulty, fusible at the highest heat of the blowpipe, with slight appearance of boiling while in the flame, but hardening to a very smooth glossy surface immediately they are removed.

Under the microscope, with a power of something over three hundred diameters, the mineral appears to be of entirely homogeneous composition, no trace whatever of admixed matter having been noticed. There was, however, an appearance on some of its surfaces of bubbles, some of them extremely minute, and only seen with a very high power, others of considerable size and readily visible to the naked eye. Other surfaces—those of fracture—showed no bubbles, even with the highest power brought to bear.

The specific gravity varies considerably in different specimens, the following being the results obtained from six different specimens:

No. 1, 3.82; No. 2, 3.805; No. 3, 3.805; No. 4, 3.856; No. 5, 3.869; No. 6, 3.827; average, 3.83.

It was not discovered that these various specimens differed in hardness.

The fracture is decidedly vitreous, conchoidal. The mineral is brittle. When ground to an impalpable power in an agate mortar, it is very light gray in color; but when ground in a steel mortar, and sifted through several thicknesses of the finest muslin, it is very much darker, though still considerably lighter in color than the lump. This is, doubtless, partly due to an addition of silica from the mortar, in the first case, but more largely to a finer state of subdivision and different shape of the particles—the one being the result of attrition, the other of impact.

The specimens observed show no signs of cleavage-planes, or crystallization, but seem to have been fused and to have taken the form of the cavity into which they had run while in a viscid state. One specimen in particular, it is true, looks very much like an octahedron, but I take it, this is merely accidental.

It is insoluble in acids and extremely difficult to decompose, even with very large excess of the mixed potassium and sodium carbonates, and long fusion over the blast-lamp.

A preliminary analysis of a sample, ground in an agate mortar, gave the following percentage composition:

SiO_2,	46.32
Fe_2O_3,	13.00
Al_2O_3,	9.19
CaO,	17.74
MgO,	13 13
MnO_2,	trace
Total,	99.38

This gives a molecular composition as follows:

SiO_2,	9.50
Fe_2O_3,	1.000
Al_2O_3,	1.097
CaO,	3.874
MgO,	4.04

A second determination of SiO_2 gave 48.865, according to which the molecular composition would be:

SiO_2,	9.86
Fe_2O_3,	1 000
Al_2O_3,	1.097
CaO,	3 874
MgO,	4.04

This corresponds very closely with the relation $2R_2O_3 : 8RO : 10SiO_2$, or, more simply,

$$R_2O_3 : 4RO : 5SiO_2.$$

Qualitatively, this mineral resembles the garnets, but quantitatively it differs from them widely, as the above relations of bases to acids indicate.

The foregoing analysis is simply given to show about what the composition is, but is not claimed to be accurate, since it is too high in silica, which the sample acquired from the mortar in grinding.

To sum up then, this mineral is fusible with difficulty; hardness, 9; specific gravity, 3.83 (average of six determinations); not attacked by HCl, HNO_3, H_2SO_4, or aqua regia; in composition, a silicate of CaO, MgO, Al_2O_3, and FeO_{23}, with an approximate relation between bases and acids of $R_2O_3 : 4RO : 5SiO_2$; opaque black; fracture, conchoidal; lustre, vitreous; color, greenish-brown by transmitted light.

I find no record of any mineral at all resembling this in compo-

sition and physical properties, and, therefore, suggest for it the name of "Ramosite," from the name of the locality where it was found.

I will add that the country for many miles in all directions from the point where the mineral was found is volcanic in origin; that the mineral has never been found *in situ*, but always, so far, in the alluvium, and that its matrix is probably the trap-rock, by the decomposition of which it has been left as now found.

Discussion.

Dr T. Egleston, New York City: I would like to ask Professor Perry whether any microscopic examination of this mineral was made with polarized light.

Professor Perry: No, sir.

Dr. Egleston: I thought you said you had made a miscroscopic examination.

Professor Perry: Of very thin splinters by transmitted light.

Dr. Egleston: That would determine at once almost to what system the mineral belongs,—by cutting a section for examination by polarized light,—it would be easier, and by it we could ascertain a good deal more nearly what the truth is. It looks a good deal like certain varieties of corundum. I think the octahedral form is accidental.

Professor Perry: Possibly, but some of the forms show distinctly that, in some cases, at least, it flowed in liquid form into a mould, and solidified there.

Dr. Egleston: I would like to ask about some topazes you sent me. What is their occurrence?

Professor Perry: In very beautiful crystals. I have here some very fine specimens of the topaz, which I will pass around. This topaz occurs in a trachytic formation.

The range of mountains constituting at this point the divide of the Mexican continent is of red porphyry. Over the bottom-land there is an outflow of trap-rock, and on the other side of the valley is an isolated butte of trachyte. This trachyte contains millions of minute crystals of topaz, and the detritus in the stream-beds is made up of these minute crystals of topaz, together with particles of the country-rock. There is a locality of over fifty acres where these crystals are comparatively abundant. One can, in a day's work, collect a pint of fair-sized crystals. I have a specimen of trachyte from that section of the country, which I brought for the purpose

of representing the occurrence of these crystals. It is as large as a hen's egg, and, I presume, contains not less than a thousand crystals of topaz. Those of the largest size are somewhat rare. All of them appear with one termination perfect, or nearly so.

THE DISTRIBUTION OF STEAM IN CITIES.

BY WM. P. SHINN, NEW YORK CITY.

In a paper contributed by W. A. Goodyear, M.E., on "Water Gas as Fuel," read at the Boston Meeting, February, 1883,* the following statement was made:

"The latest experiments on a scale of some magnitude in our cities, in the way of heating buildings and furnishing power for manufacturing purposes, have been by the distribution of high-pressure steam through pipes laid in the streets. But these experiments (1) have not hitherto been very successful; and when we consider the high cost and (2) the great and unavoidable loss of heat and power, which always accompany the conveyance of high-pressure steam to any considerable distance in pipes, to say nothing of (3) certain practical difficulties in the management of the pipes themselves, (4) it is evident that all such methods must eventually disappear before a system which can furnish a cheap gas of great heating power, easily distributed wherever wanted, without requiring pipes to stand pressures of 50 to 75 pounds per square inch, and (5) without keeping the whole mass of ground in the streets through which it passes hot, *gratis*, for a distance of ten or fifteen feet, in all directions around the pipes."

For the purpose of controverting Mr. Goodyear's statements in regard to steam-distribution in cities, I have numbered the points made in his indictment, my principal object being, not a professional discussion of the technical and theoretical merits of steam *vs.* water-gas, but a simple statement of facts, in regard to the present state of the street system of steam distribution.

Taking Mr. Goodyear's points in their order:

1. Concerning what he terms "These experiments," saying that they "have not hitherto been very successful," I propose to show, that the problem of steam-distribution has passed beyond the experimental stage, and that its practical solution is highly successful. This will be shown by the facts hereinafter fully set forth.

2. "The great and unavoidable loss of heat and power which always accompany the conveyance of high-pressure steam to any con-

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* *Transactions*, Vol. XI., p. 301.

erable distance in pipes"—is no longer a correct statement of ts. The New York Steam Company is now carrying steam in e miles of mains, ending at points from one-half to five-eighths a mile from the boiler-house. Careful investigation shows that h a pressure of 75 to 85 pounds at the boiler-house, the loss of ssure at the ends of the pipes *averages two pounds*, while a carely conducted series of experiments upon the loss by condensation, ces it in a mile of pipe, at five per cent. of the capacity of the e. This means that if a system of any number of miles does not end beyond a mile from the boilers, the loss will not exceed five cent. on the capacity of the main.

3. The "certain practical difficulties in the management of the es themselves," I suppose to refer to their expansion and contrac- n. These difficulties have been so successfully overcome by the pansion joint invented by Mr. Chas. E. Emery, engineer of the w York Steam Co., that they give no trouble whatever.

4. "It is evident that all such methods must eventually disappear," What may "eventually" occur, he would be a bold man that uld either affirm or deny; suffice it to say, what *is*: that steam-tribution is, at present, extending faster and yielding better and re practical results than "water-gas as fuel."

5. "Without keeping the whole mass of ground . . . . hot, *gra-* for a distance of ten or fifteen feet," etc. That this inference is warranted, is shown by the fact that the pipes of the New York am Co., which are laid from five to nine feet below the surface, not radiate heat fast enough to melt the snow in ordinary winter ther, any sooner over their location than it is melted elsewhere he street by atmospheric influences alone. It is no answer to s, to say that the street steam-pipes laid elsewhere or by others melt the snow. That only indicates careless, cheap or improper struction. Where mineral wool is used freely, as an insulating ering to the pipes, excessive radiation of heat does not occur.

The system of steam-distribution invented by Birdsill Holly, M. has been in successful operation in Lockport, N. Y., for heating y, for seven years. The company has four and a half miles of ins, six 75 horse-power boilers. and supplies over two hundred sumers. During the first four years, it was operated without me-, at a loss. When meters were adopted, three boilers were suffi-nt to supply the customers who formerly required the steam from The capital of the company is $50,000, and it is earning net

20 to 25 per cent. per annum. The largest main is 4 inches in diameter, and the pressure carried is 30 to 35 pounds.

In Springfield, Mass., the system has been in use for five winters, for heating only. The company has two and a quarter miles of mains, and eight 75 horse-power boilers. The pressure carried is 20 to 40 pounds. The company has 196 consumers, and on an investment of $50,000, has earned net 12 to 15 per cent. per annum, since the second year. The steam is sold by meter, and readings are taken weekly.

In Dubuque, Iowa, the system has been in operation for five winters, with two and one-eighth miles of mains, and seven 50 horse-power boilers. The company is supplying 250 horse-power of steam to 140 consumers for heating purposes only. The plant was constructed too cheaply, and has not been a financial success. It is now earning a small surplus, and consumers are all delighted with the service.

In Denver, Colorado, the system has been in use during four years, for heating only. The company has nearly three miles of eight, six, four and three-inch mains, and fifteen 50 horse-power boilers, supplying 150 consumers. Upon an investment of $150,000, the company earned net, during the season of 1882–83, $7863, or $5\frac{2}{16}$ per cent., and the net savings for the season of 1883–84 were estimated at $10,000, or $6\frac{2}{3}$ per cent.

In Hartford, Conn., a steam-plant has been in operation during four seasons, with nearly two miles of 6-inch, 4-inch and 3-inch mains, and twenty 80 horse-power boilers. This company carries 60 pounds pressure, and supplies 150 consumers, principally for heating. The plant was poorly constructed upon plans designed to evade the Holley patents, and has not been profitable, but is paying expenses, and improving in its results.

In Lynn, Mass., a "duplex system" was put in operation in February, 1881, and was run until July, 1883. This plant had a high-pressure main in which 70 pounds pressure was carried, and a low-pressure main carrying 20 pounds, the former being used for power and the latter for heating. I personally examined this plant in October, 1881, and again in June, 1882, and found it working successfully and giving great satisfaction to its customers for power, the only ones then using the steam. The plant was poorly constructed, the boiler-house was badly located, and the company failed financially; and in July, 1883, the plant was sold to a company, to be used for the distribution of water-gas. It has been so used during

the heating season just ending, with a less favorable result than was reached by the steam-company.

In New Haven, Conn., a company has been in operation for two seasons, with about two miles of 8-inch, 6-inch, 5-inch and 4-inch mains, and ten 75 horse-power boilers. The plant was constructed on the "duplex plan," and during the first season furnished both power and heat; but during the past season it has furnished 500 horse-power of steam to 80 consumers for heating only. The financial results have been bad, the earnings having failed to pay expenses, principally on account of bad management.

In Troy, N. Y., and Detroit, Mich., steam-plants have been in operation from three to four years; but I have no definite information as to their results.

In Milwaukee, Wis., a plant was constructed and operated during two winters, but owing to faulty construction and still worse management, it was a financial failure; and it has not been in operation during the last two seasons.

The New York Steam Company, after two years spent in making plans and trying experiments in expansion-joints and in non-conducting materials, began building its first boiler-station in the summer of 1881, and commenced laying street-mains in September, 1881.

The company now has its boiler-station (B) on Greenwich street above Cortlandt, in this city (a building 75 × 100 feet on the ground, with a basement and three stories complete, and the fourth story covered by a temporary roof), containing 31 Babcock and Wilcox 250 horse-power boilers, of which there are on the first floor 4, on the second floor 12, and on the third floor 15. The fourth floor contains the coal-bins, the coal being hoisted in cars, upon a platform-hoist, and descending in chutes to the floor, alongside each boiler.

The building is designed to be six stories, or 120 feet in height above the basement, and is to contain 64 boilers of 250 horse-power each; 16 on each of four floors, the fifth and sixth stories to be in one, to contain Green's Economizers, and storage for one thousand tons of coal.

The total capacity of the station will be 16,000 horse-power, requiring a daily consumption of 600 to 750 tons of anthracite coal. Draught will be furnished by two chimneys, each 27 feet 10 inches × 8 feet 4 inches interior section, and 217 feet high above the basement-floor.

The grant to the company covers the right to lay its pipes in

"every street, alley and public place" in the city of New York, which contains over 250 miles of paved streets; and the company now owns the property for ten boiler-stations, distributed on both sides of the city, from near the foot of Broad street to Fifty-sixth street.

The map herewith given shows the city from Chambers street to the Battery Park; and upon it are indicated, in black lines, the mains now laid, while the black dots show the locations of buildings in which steam is furnished by the company. The point A is to be the site of a second boiler-station, while B indicates the boiler-station now in operation.

The system of mains consists of a steam-main of 6 inches to 16 inches diameter, and a return water-main of 2½ inches to 8 inches diameter, the former laid between brick-walls, and surrounded by 6 inches to 12 inches of mineral-wool, and the latter laid in hollow logs, with a space of 3 inches around the pipes, also filled with mineral-wool. The pipes are laid with an anchorage every 90 to 100 feet, and a double expansion-joint midway between the anchorages—or with an anchorage and single expansion-joint every 45 to 50 feet. The expansion-joint is of the diaphragm style, invented by Mr. Emery for this company's use.

The mains now laid are as follows:

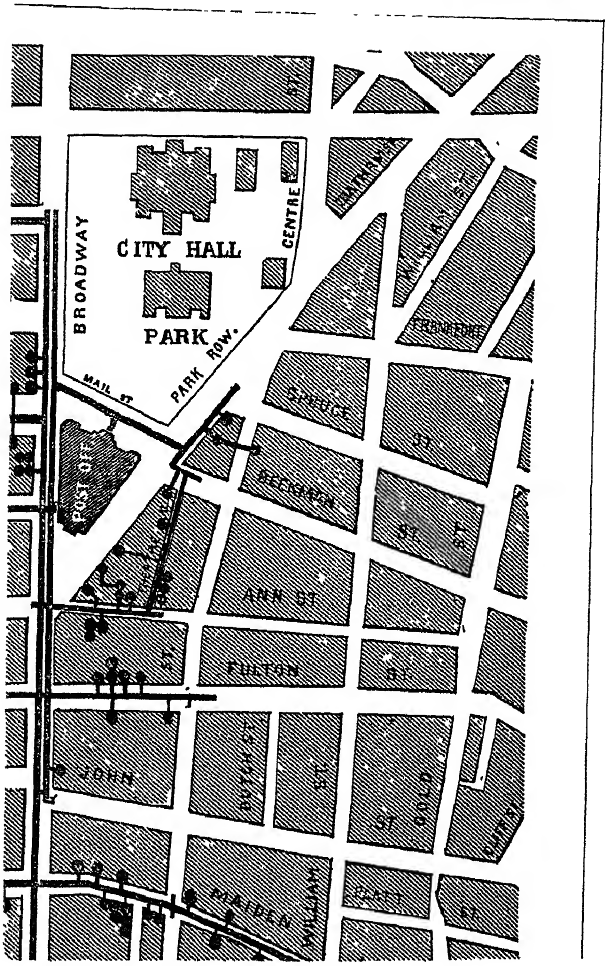
Steam-mains.		*Return Water-mains.*	
Of 16 inches . . .	746 feet.	Of 6 inches . . .	5037 feet.
" 15 " . . .	9884 "	" 5 " . . .	1155 "
" 13 " . . .	1683 "	" 4 " . . .	11900 "
" 11 " . . .	4147 "	" 2½ " . . .	3800 "
" 8 " . . .	1091 "		
" 6 " . . .	5802 "		
Total,	23,353 feet.	Total,	21,892 feet.

Or 4.42 miles of steam-mains, and 4.14 miles of return mains, in all 8.56 miles of pipes, exclusive of service-pipes.

The most distant point to which steam is now delivered is 3359 feet from the boiler-station; and the other extremities are 3187, 3133, 3044, 2973, 2920, 2880, 2625, 2261 and 2077 feet respectively, from the boiler-station.

The pressure carried is 75 to 85 pounds at the boiler-station, and carefully conducted tests show the pressure at the extreme points to be from 1½ to 2 pounds less than at the boiler-station.

The company has been furnishing, during March, 1884, 4156


BROADWAY
CITY HALL
PARK
CENTRE
PARK ROW
MAIL ST
POST OFF
CHATHAM
WILLIAM ST.
FRANKFORT
SPRUCE
ST.
BEEKMAN
ST.
ANN ST
FULTON
ST.
JOHN
DUTCH ST
ST.
GOLD
ST
CLIFF
MAIDEN
WILLIAM
PLATT

horse-power of steam to consumers, of which 1985 horse-power was for power, and 2171 horse-power for heating and other purposes.

Among the consumers now supplied are:

The Produce Exchange, new building.

The Mutual Life Insurance Company, new building.

The New York *Tribune.*

The New York *Commercial Advertiser.*

The New York *World.*

The Iron Age.

United Bank Building.

Smith and McNell, Restaurant.

All of these, excepting the two first named, formerly had their own boilers, and now take their entire steam-supply from this company.

Engines are being run of from 1 to 150 horse-power, and the supply of steam is regular, constant and satisfactory.

The amount of capital actually invested in the Station B, and its street-system, is $1,086,320.79, of which only one-half the capacity is at present being utilized; but the operations are now on a paying basis, the net earnings being at the rate of $20,000 per annum, or about two per cent. of the cost, and this in the second year of operation. When Station B is operated at its full capacity, much greater economy will be realized, and its net earnings are expected to be 15 to 20 per cent. on the amount of the investment in that part of the company's system.

From the report of a committee appointed by the Secretary of the Treasury to examine and report upon the system of the New York Steam Company, the members of which visited the principal customers of the company, I quote the following:

"Many other places where the Steam Company is furnishing heat and power might have been visited, but we deemed those herein mentioned as sufficient both in number and importance to show that the system is no longer an experiment, but a decided success.

"The advantages claimed for the system, as set forth by its projectors in their printed pamphlet, we do not consider overdrawn.

"Wherever introduced, the danger from fire or explosion, or both, is materially lessened, a more even temperature, greater cleanliness, and consequently better air and health are secured; room used for storage of coal, ashes and the débris incident to the running, cleaning and repairing of large boilers located on the premises, is made clear for other purposes, and the extra heat from such boilers, which renders valuable rooms over, or near them, unbearable in summer, is done away with.

"That steam-heat and power can be furnished by the New York Steam Company at a cost not to exceed that paid for them by the present methods, with the advan-

tages enumerated thrown in, there does not appear to be any doubt; and that with correctly registering meters and care exercised in the consumption of steam, they can be had at a cost considerably below the old system, is highly probable."

The report sets forth the advantageous working of the system quite as well as could the officers of the company; and, being the opinion of disinterested persons selected for their capacity to make a careful investigation and an intelligent report, it must be accepted as conclusive.

I claim therefore, that the system of street-distribution of steam in cities is not a failure, but that, considering the limited time for which it has been tried, it is a decided—an *unusually* decided—success.

NOTES ON IRON-ORE DEPOSITS IN PITKIN COUNTY, COLORADO.

BY W. B. DEVEREUX, ASPEN, COL.

I HAVE observed three deposits of iron ore in Pitkin County, which present unusual characteristics, and which seem to throw some light upon the genesis of iron ores under certain conditions. They occur in the precipitous mountain ranges, forming spurs on the Pacific slope of the main continental backbone.

The first is a body of limonite, lying upon the side of a high mountain, which forms part of the base of Hayden's Peak. This limonite forms a sheet of considerable area, and is thin at the edges, and about 3 feet in thickness in the central portions. It is conformable with the slope of the mountain side, and rests upon the eroded rocks, but is not comformable to them.

The ore is laminated and shaly in texture, and has the physical characteristics of the hard limonites, such as are found in the Marquette District, Lake Superior. It is covered with loose earth and rocks, from 1 to 2 feet in thickness. Much of the ore is filled with impressions of spruce leaves, such as are found in the forests now covering the slope of the mountain. In the rocks forming the mountain, iron pyrites occurs in bodies, and this limonite probably owes its origin to such a body not far distant. Not far up the mountain large masses of conglomerate are now forming, the cementing material being a similar hydrated oxide of iron. The iron is

evidently deposited by the oxidation of ferrous sulphate. In view of the evidently recent origin of these limonites, their hard compact character seems somewhat unexpected. Analyses of this ore give about 55 per cent. metallic iron and 8 per cent. silica.

A few miles distant I found limonite of almost the same chemical composition, filling a fissure vein in quartzite. The vein has been opened to a depth of 30 feet, and a sample of 20 tons gave by analysis:

Silica,	11 64 per cent.
Iron,	55.22 per cent.
Silver,	1 ounce per ton.

This ore occurs in layers parallel to the walls, which are nearly vertical, and is generally hard and dense. In addition, it shows the botryoidal structure of the so-called kidney iron-ores, viz., the rounded masses with radiations from the centre, and the delicate stripings of various forms at right angles to the radiating lines. In the massive specimens small cavities occur, lined with minute transparent quartz crystals.

The width of the ore is generally less than 2 feet, and the vein can be traced for some distance. Hydrated sesquioxide of iron, resulting from the decomposition of pyrites in place, is a not uncommon occurrence in veins; but I do not recollect having seen elsewhere in a vein a similar deposit of botryoidal limonite. The question naturally arises as to the source of the solution from which this limonite was undoubtedly deposited. I could see nothing which could form the basis of a rational explanation, and leave it, therefore, as a matter for conjecture.

Neither of the two deposits described is of special economic importance; but a third, which is located about twelve miles up the same valley, will bear comparison with the most important iron-deposits in the United States. Superficially it seems to be a body of magnetite, extending upward from an elevation of about 11,000 feet, and crossing a spur of Taylor Range. I only examined the lower end, but was told that it extended more than a mile; and, as far as I could see, the surface indicated that this was the case. The country rock consists at this point of limestone. I have made no study of it, but believe it is referred to the Silurian in the geological maps of Colorado. The strata are very much disturbed at this point, and lie at an acute angle to the vertical. Although much concealed by débris, the mass of magnetite shows direct con-

tact with the limestone, whether as a vein or as an irregular mass, cannot say. The outcrop is several hundred feet in width, and cut longitudinally by a deep ravine extending up the side of th mountain. Upon the sides of this ravine is a large quantity of loos ore, through which immense masses of solid ore protrude, ofte forming walls of considerable extent. This ore is nearly pur magnetite, showing occasional spots of pyrites and a little cal cite. It is hard, but shattered by cleavages. At the lower enc where it appears to be cut off, included masses of limestone ma be seen. Cavities are plentiful, but small, and stained browr Physically the ore is massive and partially crystalline, and shows few octahedral crystals. An analysis of a sample taken from a lo of 30 tons from the surface gave me the following result:

Silica,	1 7	per cent.
Iron,	68.79	"
Sulphur,	0.24	"

The remainder was calcite, not determined; nor was any phos phorus-test made.

While in doubt as to the relation this ore-body bears to the lime stone, I hazard the opinion that the magnetite is a direct product o the decomposition of iron pyrites, and that the ore-body at no grea depth is massive pyrites instead of massive magnetite. I base thi opinion upon the following facts: Although the surface-ore is quit free from sulphur, pyrites rapidly increases in depth where the or has been opened up. Efflorescence of ferrous sulphate is also com mon; and in the bed of the ravine the ore is a mixture of pyrite an magnetite, the latter appearing as a fine-grained gray matrix, and when pulverized or broken off, being strongly attracted by the mag net. This rapidly increasing percentage of pyrite, the occurrence o the two minerals in intimate juxtaposition, and the fact that no intermediate stage of hematite occurs, all oppose the application to thi case of the ordinarily accepted theory that magnetite is a metamorphic derivative from hematite. Having had the advantage of a somewhat extensive observation of iron-ore deposits, and accepting as satisfactory in many cases the theory just mentioned, yet in this case I can see nothing which will permit its use as an explanation of the facts. If this magnetite is a derivative from hematite, the facts observed would indicate that it has suffered a further change from magnetite to pyrite—such change extending from below upwards. This ore contains a trace of silver also, but no copper. It

may be interesting to note that pieces of the limestone referred to as forming the adjoining country-rock, emit, when struck with a hammer, the odor of sulphuretted hydrogen. Although, as remarked above, I believe that this ore-body will be massive pyrites at no great depth, yet in the indicated superficial area there must certainly be an immense quantity of magnetite of exceptional purity.

Furthermore, a down-grade of forty-five miles will take this ore to extensive fields of fine coking coal.

Since writing the above, I have been using this magnetite as flux in smelting argentiferous lead-ores with barite gangue, iron-matte being one of the products. The separation of the sulphur in matte is easily and satisfactorily accomplished.

NOTE CONCERNING CERTAIN INCRUSTATIONS ON PIG IRON.

BY KENNETH ROBERTSON, JERSEY CITY, N. J., AND FRANK FIRMSTONE, EASTON, PA.

PECULIAR crusts having appeared on certain irons made at Glendon and Pequest, which, in our experience, were entirely new, some analyses of them were made; and these analyses, together with an account of the manner of appearance of the crusts, are herewith submitted to the Institute.

At Pequest the ores were: $\frac{1}{3}$ Peters, from Ringwood, N. J.; $\frac{1}{3}$ roasted sulphurous ore, from Charlotteburgh, N. J.; and $\frac{1}{3}$ red ore (decomposed magnetite), from Chester, N. J. The fuel was $\frac{7}{8}$ Lehigh anthracite and $\frac{1}{8}$ Connellsville coke, and the limestone a dolomite from Andover, N. J. The resulting iron varied in silicon from 0 84 per cent. in No. 1 foundry to 0.51 per cent. in gray forge; in phosphorus, from 0.81 per cent. to 0.55 per cent.; sulphur, 0.035 per cent.; manganese, 0.375 per cent. It was highly "chilling" in its properties, and very strong. In running, it invariably appeared to be of a lower grade than it really was; the higher grades scintillating as much as hard iron usually does. After getting into the moulds, and beginning to cool, a black crust began to show itself, seeming to exude from the pigs, till finally, when the iron was cold enough to break, it completely covered the face of the pigs. At this time it was dense black, but after some exposure to the air it ac-

quired a purplish tinge. The higher the grade of the iron the heavier was the coating; being very heavy on foundry irons, a little less on gray forge, and hardly perceptible on mottled, while on white iron it was entirely wanting. After some experience, it served to give a very correct idea as to what the grade was before the iron was broken, and was in this respect a much more reliable guide than the appearance of the iron while running.

A sample was scraped off the faces of the pigs as they came from the cast-house and analyzed with the following result:

Sesquioxide of iron,	38.41
Silica,	45 69
Alumina,	3.56
Oxide of manganese,	4 97
Lime,	1.61
Magnesia,	0 66
Titanic acid,	5 59
Phosphoric acid,	0.06
Sulphuric acid,	trace
Chromic oxide,	0.48
Moisture,	0.24
	101.27

Afterwards a portion was taken from the iron which had been exposed to the weather for some months, and the following partial analysis was made in the laboratory of Dr. Drown:

Silica,	23.68
Titanic acid,	4.43
Manganese,	2.92
Vanadic acid,	1 82

The difference in the percentages of silica in the two analyses is doubtless caused by the pig-bed sand having been weathered off the second sample. The reporting of chromic oxide instead of vanadic acid in the first analysis, was probably an error of the chemist, who is now repeating the analysis.

The cinder which accompanied this iron was very basic, containing only 34 per cent. to 37 per cent. silica. This composition was made necessary by the sulphur in the ore-mixture.

The crusts on the iron at Glendon do not differ much in appearance and mode of occurrence from those above described from Pequest, except that they are best seen on No. 2 iron, from which they may be easily detached by scraping with a knife, while they adhere pretty firmly to the No. 1 iron.

A sample taken from No. 2 iron gave the following composition when analyzed by Mr. P. W. Shimer in Dr. Drown's laboratory:

Silica,	50 36
Sesquioxide of iron,	32.11
Oxide of manganese,	9.96
Lime,	0.10
Magnesia,	none
Titanic acid,	5.77
Vanadic acid,	1.15
Phosphoric acid,	0 12
	99.57

It was easy to see that the sample was largely contaminated with sand and dust from the pig bed, which could not be separated in collecting it; and from this source, no doubt, came most of the silica in this case.

Such crusts are very common on the iron at Glendon, and the iron that shows them is certain to be of good quality, and especially to chill well; but the absence of the crust is no proof that the iron will not be good in that respect.

On iron made at Longdale, Va., with charcoal and cold blast, what was doubtless a similar thing was seen; but as no charcoal iron has been made there for some nine years past, it has been impossible to procure a sample for analysis. This was also a good chilling iron.

The ores from which these irons were made are entirely dissimilar; the cinders were different, and the only things in common appear to be the incrustations and the lowness in silicon. Enough is not yet known about the matter to enable one to say positively that these crusts occur on all chilling irons. For this reason this note was written, in the hope that some members, having remarked such occurrences, might be induced to publish their obvervations, and that comparisons might be made, by which, if possible, a law might be established. It is even hoped that, when sufficient data have been accumulated, some one of an imaginative turn of mind may be induced to hazard a theory as to the cause of the production of these crusts, which, while it will doubtless be entertaining, will as certainly prove to have "no money in it."

Discussion.

I. P. Pardee, Stanhope, N. J.: We have had the same deposit on our pig iron at Stanhope. N. J., or, at least, what I suppose is

the same, since the description of the crust on the Glendon and Pequest irons would answer for that at the Musconetcong Iron Company's furnaces. My attention was first called to it about a year ago, and I found that when there was much of this powder, the iron was exceedingly gray, although it ran and sparkled much like hard iron. When the iron was gray-forge, little or none of this powder was ever seen. The pig, on analysis, proved very low in silicon, running, if I remember correctly, about 0.58 per cent. Si; and, on testing the iron as to its chilling qualities, the test would show almost a solid white, the iron being very gray No. 2. We do not use any hematite, or any very sulphurous ores. The ores are all New Jersey magnetite, $\frac{1}{3}$ of the mixture having 1.25 per cent. S, and the remaining $\frac{2}{3}$ having no appreciable amount of sulphur.

George Auchy, Durham Iron Works, Riegelsville, Pa. (*communication to the Secretary*): I am the chemist who made the first analysis cited in this paper. On hearing that Dr. Drown's assistant had found vanadic acid in the material, I procured from him a portion of the sample he had used. This I have carefully analyzed (not looking at the figures from Dr. Drown's laboratory until my own had been obtained), and the results as to silica, titanic acid, and manganese agree closely with his, as will be seen below. On the other hand, I found both chromic oxide and vanadic acid, and determined the former repeatedly and with special precautions. As will be seen, however, the amount is considerably less than I found in the first sample, in which I no doubt overlooked the presence of vanadic acid. I regret that the small quantity available from the second sample did not permit me to determine the vanadic acid also. It will be seen that the total of my determinations is only 98.46.

The results I obtained are as follows:

Ferric oxide (Fe_2O_3),	67.00
Silica,	22 84
Alumina,	none
Manganese oxide (Mn_3O_4),	3.80
Lime,	0.04
Magnesia,	none
Titanic acid,	4.45
Chromic oxide (Cr_2O_3),	0.15
Moisture,	0.18
	98.46
Iron,	46.90
Manganese,	2.74

The absence of alumina and magnesia, and the smaller amount of lime in the second sample, may be due to the cleaner condition of the sample, as mentioned in the paper to explain the diminution in silica. It is, however, quite likely that the composition of the crust is not uniform.

BIOGRAPHICAL NOTICE OF SIR C. W. SIEMENS, D.C.L., LL.D., F.R.S.

BY GEORGE W. MAYNARD, NEW YORK CITY.

In the death of Sir William Siemens, the Institute loses its most distinguished honorary member, one who, without exaggeration, may be ranked among the greatest men of the century. In justification of this claim, I quote in part the words of two other men eminent in the walks of science.

Professor Huxley, addressing the Royal Society, spoke of Siemens as "a marked example of vast energy, large scientific acquirements, and intellectual power of a high order," and as one "who had no superior in fertility and ingenuity of invention, while hardly any living man so thoroughly combined an extensive knowledge of scientific principles with the power of applying them in a commercially successful manner. The value of his numerous inventions must be measured, not merely by the extent to which they have increased the wealth and convenience of mankind, but by the favorable reaction on the progress of pure science which they, like all such inventions, have exerted, and will continually exert."

Dr. Wedding, in his address before the *Verein zür Beförderung des Gewerbefleisses in Preussen,* speaks of Siemens as being "so fortunate as to combine German erudition with British activity in such a manner that both nations, German as well as English, were equally proud of him; and, now that his rich life is ended, regret is expressed on both shores of the North Sea, first by the Germans that his entire life had not been spent in Germany, and his powers dedicated to Germany, and by the English that he was not born a Briton."

Germany may well be proud of being the birth-place, not only of such a man, but of such a family; for where in history shall we find in a single family such a wide range of knowledge so successfully applied to the arts? The least distinguished name in the following list has added to the world's knowledge enough to satisfy the desire for fame of any ordinary man. This constellation is made up of:

Carl Wilhelm Siemens,
Ernst Werner Siemens,
Carl Heinrich Siemens,
Friedrich Siemens,
Georg Siemens, and
Ludwig Siemens.

For the information contained in the present brief memoir, I am largely indebted to various published accounts. The most complete life which I have found is that published by Mr. W. T. Jeans in *The Creators of the Age of Steel.* I have also drawn information from Mr. J. S. Jeans' obituary notice in the *Journal of the Iron and Steel Institute.*

For what his family pronounces the most accurate sketch of our distinguished fellow-member's early life, I am indebted to the address of Dr. Wedding above referred to, kindly furnished me by Mr. Wilhelm Siemens, son of Dr. Werner Siemens, of Berlin.

Carl Wilhelm Siemens was born at Lenthe in Hanover, April 4th, 1823, and died in London, November, 1883. He was a son of one of the village officials. His first school-training was in the Catharineum at Lübeck, followed by a course at the Commercial School in Magdeburg.

In Lübeck, the German guild-system was in full force; and he repeatedly referred to it in after-life. "When a boy at school," he says, "I was living under the full vigor of the old guild-system. In going through the streets of Lübeck I saw 'Carpenters' Arms,' 'Tailors' Arms,' 'Goldsmiths' Arms,' and 'Blacksmiths' Arms.' These were lodging-houses, where every journeyman belonging to that trade or craft had to stop if he came into town. In commencing his career, he had to be bound as an apprentice for three or four years; and the master, on taking an apprentice, had to enter into an engagement to teach him the art and mystery (which meant the science) of his trade. Before the young man could leave his state of apprenticeship he had to pass a certain examination; he had to produce his *Gesellen-stück*, or journey-piece of work; and if that was found satisfactory, he was pronounced a journeyman. He had then to travel for four years from place to place, not being allowed to remain any longer than four months under any one master. He had to go from city to city, and thus pick up knowledge in the best way that could have been devised in those days. Then, after he had completed his time of travel, on coming back to his native city, he could not settle as a master in his trade until he had produced his

Meister-stück, or master-piece. These master-pieces in the trade were frequently works of art in every sense of the word. They were, in blacksmithing, the most splendid pieces of armory. In every trade, and in clocks above all others, great skill was displayed in their production. These were examined by the Masters' Committee of the guild, and upon approval were exposed at the Arms of the trade for a certain time, after which the journeyman was pronounced a master. He was then allowed to marry, provided he had made choice of a woman of unimpeachable character. These rules would hardly suit the taste of the present day; but still there was a great deal of good in those old guild practices."

Before Siemens was nineteen years old he went to Göttingen. Here, by his "iron industry," as Wedding puts it, he filled up the gaps of his school-training. Here, under Wöhler, he first got that insight into chemical laws which laid the foundation for his metallurgical knowledge, and here began to develop in him that wonderful thirst for discovery which abundant success never quenched.

Our interest in the beginnings of notable men is frequently greater than in their later achievements, after they have already become great; and I think there are few more interesting histories than that of Siemens, as related by himself in his Inaugural Address before the Midland Institute at Birmingham. Though it has probably been referred to in nearly all of the sketches of his life, I venture to think it will prove of sufficient interest to give it in its entirety here, because he always regarded the period to which it refers as the turning-point in his life.

"At that time (1841), that form of energy known as the electric current was nothing more than the philosopher's delight. Its first practical application might be traced to the town of Birmingham, where Mr. George Elkington, utilizing the discoveries of Davy, Faraday and Jacobi, established a practical process of electroplating in 1842.

"It affords me great satisfaction to be able to state that I had something to do with that first practical application of electricity; for in March of the following year (1843), I presented myself before Mr. Elkington with an improvement of his process, which he adopted, and, in so doing, gave me my first start in practical life. When the electrotype-process first became known it excited a very general interest; and although I was only a young student at Göttingen, under twenty years of age, who had just entered upon his practical career as a mechanical engineer, I joined my brother, Werner Siemens,

then a young lieutenant of artillery in the Prussian service, in his endeavors to accomplish electro-gilding—the first impulse in this direction having been given by Professor C. Himley, then of Göttingen. After attaining some promising results, a spirit of enterprise came over me, so strong, that I tore myself away from the narrow circumstances surrounding me and landed at the East-end of London, with only a few pounds in my pocket and without friends, but with an ardent confidence of ultimate success within my breast. I expected to find some office in which inventions were examined, and rewarded if found meritorious; but no one could direct me to such a place. In walking along Finsbury pavement, I saw written up in large letters, so-and-so (I forget his name), '*Undertaker*,' * and the thought struck me that this must be the place I was in quest of. At any rate I thought that a person advertising himself as an undertaker would not refuse to look into my invention, with a view of obtaining for me the sought-for recognition or reward.

"On entering the place I soon convinced myself, however, that I had come decidedly too soon for the kind of enterprise then contemplated; and, finding myself confronted with the proprietor of the establishment, I covered my retreat by what he must have thought a very inadequate excuse. By dint of perseverance I found my way to the patent office of Messrs. Poole & Carpmael, who received me kindly, and provided me with a letter of introduction to Mr. Elkington. Armed with this letter, I proceeded to Birmingham to plead my cause with him. In thinking back to that time, I wonder at the patience with which Mr. Elkington listened to what I had to say, being very young, and scarcely able to find English words to convey my meaning. After showing me what he was doing already in the way of electro-plating, Mr. Elkington sent me back to London in order to read some patents of his own, asking me to return if, after perusal, I still thought I could teach him anything. To my great disappointment, I found that the chemical solutions I had been using were actually mentioned in one of his patents, although in a manner that would hardly have sufficed to enable a third person to obtain practical results. On my return to Birmingham I frankly stated what I had found; and with this frankness I evidently gained the favor of Mr. Josiah Mason, who had just joined Mr. Elkington in business, and whose name as Sir Josiah Mason will ever be remembered for his munificent endowment of education. It was

* The literal translation of the German *Unternehmer*.

agreed that I should not be judged by the novelty of my invention, but by the results which I promised, namely, of being able to deposit with a smooth surface three pennyweights of silver upon a dish-cover; the crystalline structure of the deposit having heretofore been a source of difficulty. In this I succeeded; and I was able to return to my native country and my mechanical engineering a comparative Crœsus. Notwithstanding the lapse of time," he said nearly forty years afterward, "my heart still beats quick each time I come back to the scene of this, the determining incident of my life."

After his return to Germany, he passed a year as a pupil in Count Stolberg's engine-works. While there, he perfected a steam-engine governor which had been suggested by his brother. With this invention, he returned to England in 1841, so that he might enjoy the security afforded by the English patent-law. He now concluded to remain in England, and was naturalized in 1850. Not long after he had taken up his permanent residence in England, he married the lovely and accomplished Scotch lady whose cordial hospitality it has been the good fortune of some of us to enjoy.

Now began that wonderful series of inventions and discoveries which followed one another with almost bewildering rapidity. The list of patents and contributions to technical journals which is attached to this memoir tells the story of mental work and ceaseless energy more perfectly than the most eloquent biographer could do it. Particular attention, however, should be drawn to what may properly be called his revolutionary discoveries, in the domain of heat and electricity.

"Already in 1846 he began the study of the economy of fuel, in the light of recent investigations respecting the true nature of heat." . . . . "He read the treatises of Joule, Carnot, and Mayer, and proceeded to experiment on the principles thus brought to light. . . .

"On comparing the theoretic power of heat with the mechanical power given off by the heat applied to steam-engines and caloric engines generally, he saw there was a large margin for improvement. He at once determined to try to save or utilize some of the wasted heat; and conceived the idea of making a *regenerator* or accumulator for the purpose of retaining a limited quantity of heat, and capable of yielding it up again when required for the performance of any work. In 1847 he constructed an engine with a condenser provided with regenerators. The economy of fuel was considerable, but mechanical difficulties prevented success. He did not however abandon

the subject, for he eventually put engines into practical operation in England, France, and Germany, varying from five to forty horse-power."

Notwithstanding the great improvements which have been made in steam-engineering in the last decade, Sir William Siemens told the British Association in August, 1882, that "the best steam-engine does not yield in mechanical effect more than one-seventh part of the heat-energy residing in the fuel consumed. To obtain more advantageous primary conditions, we have to turn to the caloric or gas-engine. Before many years have elapsed, we may find in our factories and on board our ships engines with a fuel-consumption not exceeding one pound of coal per effective horse-power per hour, in which the *gas-producer* takes the place of the somewhat complex and dangerous steam-boiler. The advent of such an engine, and of the dynamo-machine, must mark a new era of material progress at least equal to that produced by the introduction of steam-power in the early part of our century."

Now that the Prophet has left us, who will undertake to fulfil the prophecy? There is no grander field for research than the one indicated by this master of investigation.

The temptation is great to follow up step by step the development of his genius; but we must resist it, and come to that part of his work which is of more direct interest to the members of the Institute.

The regenerative engine was evidently the forerunner of the regenerative gas-furnace. "In 1857, his brother Frederick suggested to him the employment of regenerators for the purpose of getting up a high degree of heat in furnaces, and he thenceforth labored to attain this result."

After many experiments and disappointments, he erected a regenerative-furnace at a glass-works in Birmingham, which proved a success.

The history of this period is so interesting that it will bear repeating at considerable length. It is well told by Mr. W. T. Jeans.

In 1862 Professor Tyndall lectured before the Royal Institution on the "Mechanical Theory of Heat," paying eloquent tribute to Mayer and Joule.

"A fortnight later, an account was given at the same institution of Mr. William Siemens's regenerative gas-furnace, *the greatest triumph in the practical application of the principles enunciated by Mayer and others.* That lecture was delivered by Michael Faraday,

the prince of pure experimentalists; and it has the historic interest of being the last lecture he was able to deliver. The circumstances in which it was delivered were memorable. Some weeks previously, Siemens received the following letter from Faraday: 'I have just returned from Birmingham, where I saw at Chance's works the application of your furnaces to glass-making. I was very much struck with the whole matter. As our managers want me to end the 'Friday evenings' at the Royal Institution after Easter, I have looked about for a thought, for I have none in myself. I think I should like to speak of the facts I saw at Chance's, if you have no objection. If you assent, can you help me with any drawings, or models, or illustrations, either in the way of thoughts or experiments? Do not say much about it out of doors as yet; for my mind is not settled in what way, if you assent, I shall present the subject.'

"Siemens readily assented, and spent two days at Birmingham in showing Faraday over the works where his furnaces were in operation. On the appointed Friday evening, June 20th, 1862, the venerable *savant* appeared before the Royal Institution for the last time, to explain the wonderful simplicity, power, and economy of the regenerative gas-furnace. In the course of his lecture, which lasted about an hour, and which he concluded by bidding his audience a pathetic farewell, he accidentally burned his notes; and he was only able afterward to give the abstract of it that is published in the *Proceedings*."

The almost universal adoption of the Siemens heating-furnace in iron and steel-works, and in operating the open-hearth process, is too well known to make it necessary for me to dwell upon the merits of either.

Through the courtesy of Messrs. Richmond and Potts, the agents of Messrs. Siemens in this country, I am enabled to furnish the following interesting facts about the adoption of the Siemens furnace in the United States.

The first Siemens heating furnace was started September 26th, 1867, at the works of the Nashua Iron Company, Nashua, N. H.

A small open-hearth steel-melting furnace, built at Trenton at the works of Cooper, Hewitt & Co., was started in December, 1868, but it has never been worked with any degree of regularity.

In January, 1870, an open-hearth steel-melting furnace was started up at the Bay State works in South Boston, and was the first furnace of that kind put regularly to work in this country.

The first crucible steel-melting furnace was built at the works of Anderson & Woods, Pittsburgh, and was started November 2d, 1867.

There have been built in this country: 165 Siemens furnaces for heating iron and steel; 58 open-hearth furnaces; 56 crucible-steel furnaces, and over 30 furnaces for sundry other purposes, such as glass-melting, zinc-smelting, puddling, etc.

It is strange that abroad the Siemens furnace is in use for the manufacture of *glass* to a greater extent than for any other purpose, and yet it is applied to that branch of manufacture in but few cases in this country. The annual capacity of the Siemens furnaces in use in this country may be stated as follows:

Heating-furnaces, ...	2,000,000 tons.
Open-hearth furnaces, ...	350,000 "
Crucible-furnaces, ...	70,000 "

It is safe to say that of the total production of wrought-iron and steel in the United States, fully one-third is heated in Siemens's furnaces, and practically all of the open-hearth steel and two-thirds of the crucible-steel is made in these furnaces. If we place the amount of iron and steel heated per annum by the Siemens furnaces at 1,500,000 tons, and consider the saving at $2.50 per ton, we have an annual saving of $3,750,000. The production of open-hearth steel in 1883 was about 2,000,000 tons; and it is safe to estimate the saving in making this steel at $20 per ton, over any other method of producing the *same quality* of product. Crucible-steel manufacturers readily accord a saving of $10 per ton by using the Siemens furnace, and at least 60,000 tons were produced in 1883.

Mr. Jeans, in the *Journal of the Iron and Steel Institute*, says: "Until 1873 the total quantity of open-hearth steel produced in the United Kingdom was 77,500 tons. During the next two years this figure was not much improved upon; but in 1876 the product had advanced to 128,000 tons; in 1878 to 174,000 tons; in 1880 to 251,000 tons; and in 1882 to 436,000 tons."

The estimated quantity for 1883 is 500,000 tons. At the end of 1883 fully 370 open-hearth furnaces had been erected throughout the world, equal to an annual production of about 1,500,000 tons.

Siemens always talked of the ultimate success of his "direct process" with as much confidence as of any of his inventions. Had his life been prolonged, I have no doubt that he would have achieved success in this direction, and would have made the direct process a necessary adjunct to the open hearth.

A discussion of his triumphs in other branches of science as applied to the arts will not properly find a place in this communica-

tion. A glance, however, at the record attached, leads one to think that that work in which we are most interested, held but a subordinate place among his thoughts and deeds.

In 1876 Dr. and Mrs. Siemens paid a short visit to this country, and always after spoke with pleasure of the country, its resources and development, and the hospitality of its people.

"Sir William Siemens filled many positions of distinction, both public and private, and was the recipient of many honors. In addition to the Bessemer Gold Medal of the Iron and Steel Institute, presented to him in 1876, he received in 1874 the Albert Gold Medal of the Society of Arts, which also, as early as 1850, awarded him a gold medal for his regenerative condenser. In 1853 he received from the Institution of Civil Engineers, the Telford Medal for his paper 'On the Conversion of Heat into Mechanical effect;' and only a short time before his death the same institution conferred on him the Howard Quinquennial Prize. He also received prize-medals at the International Exhibitions of 1851, 1862, and 1867. Few men have filled within so short a time so many presidential chairs. He was president of the Institution of Mechanical Engineers (1872), of the Society of Telegraph Engineers and Electricians (1875), Iron and Steel Institute (1877), and of the British Association (1882); while in the latter year he was also elected to preside over the Council of the Society of Arts; and in 1881 he was elected a vice-president of the newly formed Society for the Promotion of Chemical Industry. He was besides, in 1862, made a fellow, and in 1869 a member, of the Council of the Royal Society. He was a D.C.L. of Oxford, and an LL.D. of Glasgow University, and, finally, in March, 1883, he received from Her Majesty the honor of knighthood."

Concerning my personal relations with him, this is not the place to speak at length. It is needless to say that I was thus laid under the deepest obligations of gratitude, as well as impressed with the most vivid sentiment of affection and esteem. In company with a worthier guest,—the brilliant and lamented Holley,—it was my privilege to learn, by personal and profitable experience, the hospitality of the home and the generosity of the heart of Charles William Siemens. In this respect—of lavish kindness to their professional colleagues (or, let me rather say, disciples)—Siemens and Holley were congenial spirits; and we may say of the former, as well as of the latter, that in his departure we have lost, not merely a leader, but also a friend.

APPENDIX I.

RECORDS OF THE WORK OF C. WILLIAM SIEMENS.

CHRONOLOGICALLY ARRANGED.

Year.	NAME, TITLE, Etc.	Dingler's Polytechnisches Journal.		Telegraphic Journal (Electrical Review.)		The Electrician.		Journal of the Society of Telegraph Engineers and Electricians		London Engineering		Miscellaneous Publications.
		Vol.	P.	Vol.	P.	Vol.	P.	Vol	P.	Vol.	P.	
1845	Differential Governor Werner and C. William Siemens. (Illustrated),	98	81									
1846	Patented Improvements in Steam-Engines and especially in Steam Governors,	99	475									
1847	Anastatic Printing, by Siemens Brothers, London,	105	75									
1847	Process for Dissolving Kaolin for the Production of Artificial Stones Werner and C. William Siemens,	106	448									
1848	Patented Improvements in Steam, and other Engines worked by Elastic Fluids,	108	152									
1849	Patented Improvements in Steam-Engines and in the Process of Evaporating Liquids,	112	394									
1851	Siemens' Patent Regenerative Condenser,	122	402									
1852	New Regenerative Condenser for High and Low Pressure Engines (Illustrated),	123	249	...	...	...	...	...	...	...	...	Report of the Proceedings of the Inst. Mechanical Engineers.
1852	Patent for an Improved Means of Measuring Liquids,	126	70									
1852	The Expansion of Dry Steam, and the Total Heat of Steam. (Illustrated),	127	81									
1853	On the Conversion of Heat into Mechanical Effect,	..	..	..	...	..	..	..	...	...	...	Transactions, Inst. Civil Engineers
1853	On an Improved Governor for Steam-Engines,	..	..	..	...	..	...	..	..	..	...	Report of the Inst. of Mech. Eng
1854	The Siemens Water Meter. (Illustrated),	134	243									
1855	Improvements in Electric Telegraphs, Patented by William Siemens in England (Illustrated),	138	176									
1855	The William Siemens Engine with Regenerative Steam. By F Moigno,	138	241									
1855	The Regenerative Steam-Engine,	.	...	...	...	...	...	...	...	..	...	Mechanics' Magazine, vol. 65, p. 55
1856	Apparatus for the Simultaneous Dispatch of Telegraphic Messages in Opposite Directions on a Single Wire. Patented in London,	139	161									
1857	Efficiency of the Siemens Steam-Engine with Regenerated Steam,	143	463									
1857	New Design of Furnaces,	146	174									
1857	The Siemens Water Meter [see Vol. 134]. (Illustrated),	146	334									

1857	Improvements in Cooling and in Freezing Water and other bodies,	...	...	...	...	...	...	...	...	...	...	Report of Pat Invent. (2), vol 27, pp. 296–299.
1858	Heating-Furnace, in which the Heat of the Product of Combustion is largely Retained and Utilized. C. Wm. Siemens and F. Siemens. (Illustrated),	147	273									
1858	On the Progress of the Electric Telegraph,	...	...	...	...	...	...	...	...	...	...	Journal of the Society of Arts.
1860	The Cause of the Explosion at St. Mary's Church,	...	...	...	...	...	...	...	...	...	...	Committee Report to the Hebdomadal Council, Oxford, 1860.
1860	Outline of the Principles and Practice Involved in Dealing with the Electrical Conditions of Submarine Electric Telegraphs. Dr. Werner and C. W. Siemens,	...	...	...	...	...	...	...	...	...	...	Brit. Ass., Oxford, 1860 German trans Zeitschr.d deutsch-oesterr. Tel.-Vereins
1861	On a New Resistance Thermometer,	...	...	...	...	...	...	...	...	...	...	Report Brit Ass (2), p. 44. Phil. Mag. (2), vol 21, p 73.
1861	On the Bathometer, an Instrument to Indicate the Depth of the Sea on Board of Ship without Submerging a Line,	...	...	...	...	...	...	...	...	...	...	Report Brit. Ass (2), p. 73.
1861	On Fire and Railway Alarms,	...	...	...	...	...	...	...	...	...	...	Civil Engineer, p. 308.
1862	Regenerative Gas-Engine,	...	...	...	...	...	...	...	...	...	...	Polyt Centr.-Blatt, p. 1457.
1862	Regenerators with Gaseous Fuel C. W Siemens and F. Siemens, in London Their Adaptation for Glass Melting Furnaces. By C. Schinz. (Illustrated.) See Dingler's Journal, Vol 146,	166	270									
1862	Electrical Instruments and Telegraphic Apparatus. Records of the International Exhibitions,	...	...	...	...	...	...	...	...	...	...	Practical Mechanics' Journal.
1863	Patent Regenerative Gas-Furnaces. C W Siemens and F Siemens,	...	...	...	...	...	...	...	...	...	...	Published, London, 1863.
1864	The Magneto-Electric Type-Writer of Siemens & Halske, in Berlin. Report by C Wm. Siemens on the Electric Instruments and Telegraphic Apparatus at the International Exhibition in London, 1862. (Illustrated)	171	48									
1864	The Electric Conductivity of Gutta Percha and India Rubber under various Pressures,	171	234	...	...	...	...	...	...	...	...	Cosmos, vol 23 p 354
1866	On Uniform Rotation,	...	...	...	...	...	...	...	...	...	...	Philosophical Transactions.
1866	Governors for Small and Large Engines. (Illustrated),	180	409									
1867	On a Measurer of Resistance,	...	...	...	...	...	...	...	...	...	...	Brix Zeitschr d. deutsch-oesterr. Tel.-Ver., vol 14, p 76, and Phil Mag., vol 34, p 270
1867	The Electric Illumination of Buoys,	...	...	...	...	...	...	...	...	...	...	Report Brit Ass (2); p 14.
1867	Discours sur Mécanique,	...	...	...	...	...	...	...	...	...	...	Mousles (2), vol 21, pp 10–21.
1868	The Machinery used in Laying a Cable under the Mediterranean. (Illustrated),	187	24									
1858	A New Instrument for the Practical Measurement of Electric Resistance in Wires (Illustrated),	187	303									
1868	The Manufacture of Cast Steel direct from the Ore, by means of Regenerative Gas-Furnaces. (Illustrated),	189	227	...	...	...	...	...	...	...	...	Lecture before the Chemical Society.
1868	The Process of Puddling Iron,	190	203	...	...	...	...	...	...	...	...	Paper before the Brit. Ass. at Woolwich.
1869	New Process for the Manufacture of Cast Steel by Means of Regenerative Gas-Furnaces (Illustrated),	193	213									
1869	Electric Balance Thermometer for Submarine Thermometric Observations,	198	516	...	...	...	...	...	...	...	...	Mechanics' Magazine, May, 1869.

APPENDIX I.—Continued.

Year.	NAME, TITLE, Etc.	Dingler's Polytechnisches Journal.		Telegraphic Journal (Electrical Review)		The Electrician.		Journal of the Society of Telegraph Engineers and Electricians.		London Engineering		Miscellaneous Publications.
		Vol.	P	Vol	P.	Vol.	P	Vol.	P.	Vol	P.	
1870	Siemens' Pyrometer,	198	258									
1870	Pyrometer of C. William Siemens (refer to preceding article). Discussed by C. Schinz,	198	394									
1871	Note on the Blast Pipe,	. .		.	. .	. . .	. .	. .	. .	. . .	. .	Polyt. Centr. Blatt, pp. 1413–17.
1871	Electric Pyrometer,	201	41									
1871	On the Steam Blast,	.	.	. .	. . .	. .		. . .	. .	. .	. . .	Report British Association.
1872	Siemens' System of Blowing Engine,	203	10									
1872	The Steam-Jet Exhauster, and its Application,	205	521	. .	. .	. .	. .	. . .	. .	. .	. .	Proceedings, Inst. Mech. Eng., Birmingham
1872	On Pneumatic Despatch Tubes, the Circuit System,	. . .	. .	. .	. . .	. . .	. . .	.	. .	. .	. .	Institute of Civil Engineers, vol 3
1872	Siemens' Pneumatic System of Forwarding Dispatches. Note from the London Exhibition, by J Zeman,	206	3									
1872	Siemens' Combined Roasting and Shaft Furnace. (Illustrated),	206	182									
1872	The Electric Telegraph; its Improvements and Capabilities,	.	. .	. .	. . .	. .	. . .	1	19		. . .	Inaugural Address, Society of Tel Engineers, Nature vol 6, p 282
1872	Measuring Temperature by Electricity,	. . .	. .	.	. . .	. . .	. . .	1	123	.	. .	Address before the Royal Institute
1873	Iron Telegraph Poles,			1	79	. . .	. . .	2	49			
1873	Application of the Steam-Jet for the Aspiration or Compression of Gases,	207	265									
1873	On the Manufacture of Iron and Steel by Direct Process,	.	. .	. . .	. .	. . .	.	. .	.	. .	.	Paper at the April Meeting of the I and S. Inst Published in German by Springer, Berlin.
1873	Siemens' Rotator for the Production of Iron and Steel direct from the Ores. (Illustrated.) Note from the Vienna Exhibition of 1873, by J. Zeman,	209	1									
1873	On Fuel; a Lecture to the Operative Classes at Bradford, Sept. 1873,	.	.	. .	.	. . .	.	. .	. .	. . .	. .	Report British Association. German Trans., Jul. Springer, Berlin.
1873	The Electric Pyrometer. (Illustrated),	209	419	1	293							
1874	On the Dependence of Electrical Resistance on Temperature,	.	. .	. . .	. .	. .	. .	3	279			
1875	C. Wm. Siemens' Electric Pyrometer. (Illustrated),	217	291									
1875	Electric Resistance Thermometer and Pyrometer,	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. . .	. .	Transactions of the Society of Telegraph Engineers.
1875	A Copper-Steel Wire for Telegraphic Purposes, from the Factory of Siemens Brothers in Woolwich,	217	384									

1876	Siemens' Magneto-Electrical Annunciator. (Illustrated),	220	40									
1876	Hydraulic Press for Billets,	220	214									
1876	The Bathometer and an Instrument for Measuring Attractions. (Illustrated),	221	48	...	...	...	...	...	...	...	...	Philosophical Trans. Royal Society. German Transl., Jul. Springer, Berlin.
1876	Instruments for Measuring the Speed of Ships. Froude & Siemens,	...	...	...	...	...	...	...	...	...	...	Athenæum (2), p. 374.
1877	Siemens' Water Meter,	224	504									
1877	Siemens & Adamson's Patent on Water Meters,	225	140									
1877	Siemens Direct Process in the Production of Iron and Steel,	...	...	5	253							
1877	President's Inaugural Address,	...	...	...	...	...	...	...	...	...		Transactions Iron and Steel Inst.
1878	President's Inaugural Address,	...	...	...	...	...	...	...	...			Transactions Society of Tel Eng.
1878	Biography of Dr Werner Siemens,	...	...	6	324							
1878	Siemens' Patent Water Meter,	228	371									
1878	Construction of Vessels to withstand High Internal Pressure,	228	471									
1878	On the Direct Process for Manufacturing Iron and Steel,	239	84									
1879	Measuring and Regulating the Electric Currents,	...	...	7	77	...	...	...	...	...	...	German Transl., Jul Springer, Ber
1879	A Regulator for Electric Currents,	232	516	...		...	...		...	...		Proceedings of the Royal Society.
1879	Uebertragung und Vertheilung von Energie Vermittelst des Elektrischen Stromes,	...	...	...	...	...	...	...	...	...	...	Published by Jul Springer, Berlin
1879	Fabrikation des Stahls und Seine Verwerthung für Militärische Zwecke,		...	...	...		...		...		...	Published by Jul Springer, Berlin.
1879–80	The Smoke Question,	...	...	...	...				...		...	Reprint of Letters to the Times and Nature German Translation, Springer, Berlin.
1880	Improvements in the Process and the Furnaces for the Manufacture of Iron and Steel,	235	369									
1880	Siemens' Patent on Water Meters for Measuring very small quantities of Fluids,	235	396									
1880	Apparatus for Regulating and Directing the Electric Current for Illuminating Purposes,	236	501									
1880	Patented Improvements on Electric Lamps,	238	351									
1880	Patented Circular Regenerative Furnace for Baking Pottery and Porcelain,	238	415									
1880	A Magnetic Ore-Dressing Machine. (Illustrated),	238	462									
1880	On the Dynamo-Electric Current, and on Certain Means to Improve its Steadiness,	...	...	8	95							
1880	On the Influence of the Electric Light upon Vegetation, and on Certain Physical Principles Involved,	...	...	8	121	4	200	9	278			
1880	On the Applications of the Dynamo-Electric Current to Fuse Refractory Materials in Considerable Quantities,	...	...	8	123	...	...	...	...	...	...	Paper before the Society of Telegraph Eng. German Translation, Jul Springer, Berlin.
1880	Electric Mine Exploders Siemens' Apparatus,	...	...	8	273							
1880	Dr. Siemens at the Society of Telegraph Engineers,	...	...	...	...	5	42					
1880	On Dynamo-Electric Machines,	...	...	...	...	...	...	...	...	29	228	
1880 81	Gas and Electricity as Heating Agents,	...	...	...	...	6	164	...	...	...		Lecture before the Glasgow Science Lectures Association.
1881	Description of Siemens Brothers' Telegraph Works,	...	...	...	...	...	...		...	32	379	
1881	Suggestions to Gas Manufacturers,	...	...	...	...	7	104					
1881	On some Applications of Electric Energy to Horticultural and Agricultural Purposes,	...	...	9	351	7	269		...	...	...	Paper before the British Association, at York, September.

APPENDIX I.—Continued.

Year.	NAME, TITLE, Etc.	Dingler's Polytechnisches Journal. Vol	P.	Telegraphic Journal. (Electrical Review) Vol	P.	The Electrician. Vol	P.	Journal of the Society of Telegraph Engineers and Electricians Vol	P.	London Engineering Vol	P	Miscellaneous Publications.
1881	A Contribution to the History of Secondary Batteries,			9	376							Paper read before the British Association, September, '81.
1881	Note on the Appointment of C W Siemens to the Position of "Officer of Public Instruction," by the French Government,			9	405							
1881	Patented Improvement of a Rotating Puddling Furnace,	242	123									
1882	Patented Improvement on Gas Burners,	244	442									
1882	Manufacture of Iron by the Direct Process,	245	29							34	148	
1882	Influence of the Electric Light on Vegetation,	245	191									
1882	Experiments on the Fusion of Metals by the Dynamic-Electric Current,	246	463									
1882	President's Address to the British Association,			11	143	9	342					
1882	Telephonic Conductors,			11	159							
1882	The Electro-Magnetic Practical System of Units,			11	196							Paper read before the British Association, Southampton
1882	The Electric Furnace. Siemens & Huntington,			11	239	9	418					Paper read before the British Association Published in German by Springer, Berlin.
1882	Dynamo-Electric and Electro-Dynamic Machines,			11	271							
1882	Inaugural Address to the Society of Arts,			11	408	10	17					
1882	On the Conservation of Solar Energy,											Proceedings of the Royal Society, No 219
1882	Gas Producer and Motor. (Patent),									33	271	
1882	A New Theory of the Sun,											Nineteenth Century, No 62, p 510
1882	Railway Gong Signals,									33	195	
1882	Siemens' Regenerative Gas Burners,									34	328	
1882	Electric Lighting. Address before the Society of Arts,									34	476	
1882–83	The Electrical Transmission and Storage of Power,					10	447					Lecture before the Institution of Civil Engineers
1883	A Method for Increasing the Durability of the Lining of Reverberatory Melting Furnaces,	247	331									
1883	Note on the Portrush Electric Railway, built by Siemens Brothers, London, and Experiments with an Electric Elevator,	249	161									
1883	Patent of Siemens Brothers on Improvements in the Arc Light,	249	297									
1883	German Patent for Repairing the Interior of Rotating Furnaces,	249	442									
1883	On the Conservation of Solar Energy,											A Collection of Papers and Discussions, London, 1883
1883	Die Neuesten Errungenschaften der Wissenschaften,											German, Jul Springer, Berlin
1883	Die Elektrische Beleuchtung,											German, Jul Springer, Berlin

APPENDIX II.

English Patents* Granted to the Messrs. Siemens.

The initials in the first column of the table stand for: C W. S., Charles William Siemens, E W S., Ernest Werner Siemens; C H S, Charles Henry Siemens; F S, Frederick Siemens; G. S., George Siemens; L. S., Louis Siemens; v H. A., von Hefner Alteneck. The S. has been omitted where two names occur in one line.

Patentee	No	Date	Subject.
C W S.	11021	24. 12 45.	Regulating power and velocity of steam engines
C W. S	12006	22. 12 47	Engines to be worked by steam or other fluids
C W S	12531	20 3 49.	do do. do do.
E W S.	13062	23. 4 50	Electric telegraphs.
C. W S	14060	15 4. 52	Fluid meter
C W S	326	9 10 52	Steam engines
C W S.	712	23 3 53	Rotatory fluid meter
C. W S	459	25. 2 54	Electric telegraphs.
C W S	2366	8 11 54	do.
C. W S	1105	16. 5 55	Apparatus for freezing water.
C. W. S	2514	7 11 55	Evaporation of brine
C. W S.	1363	9. 6 56.	Engines with superheated steam.
C W. S	2107	10. 9 56.	Electric telegraphs.
C. W S	2824	29. 11. 56.	Fluid meters.
F S.	2861	2 12 56	Furnaces.
C. W. S.	1320	11. 5 57	Furnaces.
C W S	2061	29 7 57	Apparatus for making ice.
C. W S	1457	28 6 58	Cleansing tidal rivers.
C W S.	2074	13 9. 58.	Refrigerators
C. W & E. W.	2180	30. 9 58	Electric telegraphs.
C. W S.	87	11 1 59	Supports for telegraph wires
C W & E W	512	25 2 59.	Electric telegraphs
C W & E W.	2503	3. 11 59	Insulating electric telegraph conductors.
C W S	519	25. 2 60	Electric telegraph cables
C W S.	2074	28. 8. 60	Steam engines.
C W S	2982	5. 12. 60.	Fluid meters.
C W & F	167	22 1 61.	Furnaces.
C. W. & E W.	281	31 8. 61.	Electric telegraphs
C. W. S.	2805	8 11. 61.	Armored war vessel.
C W & E. W.	59	9 1. 62	Insulating electric telegraphs.
C. W. & E. W.	1540	22. 5. 62	Electric telegraph apparatus.
C. W. S.	2143	28 7. 62.	Gas engines
C. W. S.	464	20. 2. 63	Insulating electric telegraphs.
C. W & F.	972	18. 4. 63	Furnaces
C. W. & E. W.	2826	13. 11. 63	Submarine cables.
C. W. S.	1447	10. 6. 64.	Manufacture of glass.
C. W. S.	3018	3. 12. 64.	do. do.
C. W. & E. W.	3260	31. 12. 64.	Apparatus for motive power.
C. W. S.	1230	2 5. 65.	Regulating velocity of machinery
C. W S	2391	19. 9. 65.	Separating dust in iron blast furnaces.
C. W. S.	671	5 3. 66.	Zinc furnaces
C W S.	2413	20 9. 66	Ore-smelting furnaces.
C. W. & E. W.	3090	24 11. 66	Pneumatic despatch
C. W. & E. W.	261	31. 1. 67.	Methods of developing powerful electric currents
C W. & E. W.	631	7. 3. 67	Fluid meters.
C. W & E W.	1532	23 5. 67.	Pneumatic despatch.
C. W. S.	2395	21. 8. 67.	Ore-smelting furnaces.
C. W. S.	1172	7. 4. 68	Gas regenerative furnaces.
C W. & E W.	1253	17. 4. 68.	Electric measurements of distances.
C. W. S.	1462	5. 5. 68	Steel furnaces.
C. W S.	1892	10. 6 68.	do.
C. W. S.	3501	18. 11. 68	Fastening telegraph wires.
C. W. S	3569	24. 11. 68	Steel furnaces
C. W S.	1575	21. 5. 69.	Smelting furnaces.
C. W. S.	2988	14. 10. 69	Steel furnaces.
C. W S.	34	5. 1. 70.	Regenerative hot-blast furnaces.
C. W S.	594	28. 2. 70.	Treatment of iron ores.
C. W. & F.	1513	25. 5. 70.	Regenerative gas furnaces.

* It was obviously not necessary to give the American, German, or other patents, which were in all cases, I believe, for inventions substantially covered by the English patents.

PATENTEE	No.	DATE.	SUBJECT.
C W. S	3134	30. 11 70	Treatment of iron ores
C W S	3255		Improvement in means for exhausting receivers
C. W S.	292	2 2 71	Cast steel.
C W. S.	1959	26. 7 71.	Smelting iron ores.
C W. S.	3077	15 11. 71	Treating iron ores
C W S	1998		Electric telegraphs
C H S.	1473	15. 5. 72	Telegraphs
E W S	1919	25 6. 72	Obtaining and applying electric currents.
F S	2152	18. 7 72	Glass furnaces
C W S	2861	28. 9 72	Iron and steel furnaces.
C. H & E W.	2923	3 10 72	Telegraphs
C. W & F.	3478	21. 11 72	Glass furnaces
C W S.	3642	3 12. 72	Smelting furnaces.
E. W. & v. H A.	2006	5. 6 73	Electric light
E. W. & v. H A.	2225	27 6 73	Electric telegraphs.
F. S	2246	28 6 73	Caloric engines.
G. & de Grousilliers.	2838	28. 8 73	Soda and potash
C. W S	4075	11. 12 73	Iron and steel manufacture
C W. S.	428	74	Treating puddled balls.
E W. S.	1307	16. 4. 74	Telegraphic signals.
C. W & Stein.	3457	74	Calcining kilns.
C. W. S	43	5. 1. 75	Furnaces.
C. W. S.	1551	28. 4 75	Glass furnaces
F S	1637	3 5 75.	Hardening glass
C W S.	1540	20. 4 76.	Iron and steel to resist shock.
F & Mason.	1657	28. 4. 76	Tempering glass
F. S	2097	20 5. 76	Ornamenting toughened glass.
C W S.	3370	5. 9. 76	Iron and steel
C. W S.	3714	22. 9. 76	Iron and steel furnaces.
F. & Heese.	3904	10 10. 76	Pottery kilns.
C. H & E. W.	4685	10. 12 76	Telephones.
F S.	4780	11. 12. 76	Glass
C W. S.	4793	17 12 76	Armor-plating.
C W. S.	251	19. 1 77	Electric telegraph conductors.
C. W. S.	700	20. 2 77	Regenerative gas furnace.
C. H. S.	1871	14 5 77	Recording electric telegraph signals.
C. W. S.	2281	7 6 77	Electric lamps
E W. & v H. A.	3134	8. 8. 77	Reproducing electricity for illumination.
C H. S.	4685	10 12. 77	Telephones
C. W. S	251	19. 1. 78	Electric telegraph conductors.
C W S	700	20. 2. 78	Regenerative gas furnace.
C. W S.	2281	7. 6. 78	Distributing electric currents to lamps.
C H & E W.	2527	25. 6 78	Telephones
C. H. & E. W. & v. H. A.	3134	8. 8. 78	Producing and regulating electric currents for lamps.
C. W S.	3315	22 8 78	Electric lighting.
C W. S.	4208	22 10. 78	Electric illumination.
C. W. & v. H. A.	4949	4. 12 78	Electric lamps.
C W. S	694	20. 2 79.	Ordnance
C. W. & F.	1118	20. 3. 79.	Annealing glass
C W. S.	2110	27. 5. 79.	Light and heat by electricity.
L. S. & Justushofen	2199	3. 6. 79.	Lighting by electricity.
F S	2231	5. 6 79	Lamps and burners.
C W. & v H. A.	2652	1. 7. 79.	Electric lamps.
C. W. S.	2775	8. 7 79	Tension bars
F. S.	3555	4. 9 79.	Burners.
C W. S	4534	6. 11 79	Dynamo machines.
C W. & F.	4763	22 11. 79	Moulding glass.
F S.	5135	15. 12. 79	Moulding and annealing glass.
C W. S.	5150	16. 12. 79.	Iron and steel manufacture.
C. H & E W.	583	10. 2. 80	Conveying persons by electro-motive power.
F. S.	1561	16. 4. 80.	Lamps
C. W. S.	3374	19. 8 80.	Gas furnaces.
C. W. S.	4614	10. 11. 80	Electric lamps.
C. W. S.	4683	13. 11. 80	Gas lamps.
F. S	5172	10. 12. 80	Lamps.
C. W. & Boothby.	696	17. 2. 81.	Electric brakes.
C. W. S.	883	1. 3. 81.	Iron and steel manufacture.
C. W. & Halske.	1447	1. 4. 81.	Dynamo machines.
C. W. S.	2504	9. 6. 81	Gas motors.
F. S.	2638	17. 6. 81.	Lamps.
C. W. S.	2651	17. 6. 81.	Steel manufacture.
C. W. S.	3792	31. 8. 81.	Steel manufacture.
C. W. S.	5350	7. 12. 81.	Gas engines.
C. W. & F. J	231	17. 1. 82.	Telephone conductors
C. W. & E. W.	760	16. 2. 82	Dynamo-electric machine.

*PHYSICAL AND CHEMICAL TESTS OF STEEL FOR BOILER- AND SHIP-PLATE FOR THE UNITED STATES GOVERNMENT CRUISERS.**

BY PEDRO G. SALOM, CHEMIST AND SUPERINTENDENT OF STEEL DEPARTMENT, CHESTER ROLLING MILLS, THURLOW, PA.

I HAVE had an opportunity, within the last few months, of making a large number of physical and chemical tests of steel for boiler and ship-plate, which has been, and is now being, used principally for the United States Government cruisers, now building in Mr. John Roach's yard, at Chester, Pa. Through the courtesy of the Messrs. Houston, of the Chester Rolling Mills, I have the honor to lay before the members of the Institute the results of these tests. These results have developed some points in regard to the nature of steel, which are more or less new, and which, I hope, will prove interesting.

The original specifications, as regards the *manner* of testing, were so impracticable (when their severity was taken into consideration), that the keel of the first vessel, which will be launched next month, would, had they been carried out, probably not have been laid until next year. At my suggestion, in order to simplify and expedite the immense amount of testing that had to be done, the Naval Advisory Board was induced, after considerable discussion, to alter the specifications, so as to test each heat, instead of each lot of twenty plates, but reserved the right of making the quenching-test on a piece from each ingot, after it had been rolled.

This relieved us from the anxiety of having a lot of plates rejected, after they had been rolled and sheared, by reason of the presence of one or two plates which might have been injured in heating or rolling, or which might not have been able to stand the tests; while it insured the Government in obtaining a uniform quality of steel, and prevented the temptation to introduce a half-dozen or more bad plates in a lot, and run the risk of their being selected as the test-plates.

I give below a portion of the original specifications, as prescribed

* The discussion of this paper at the XXXIXth (Chicago) Meeting, May, 1884, will be found in vol. xiii. of the *Transactions*.

by the Naval Advisory Board, in order to insure the fulfilment of the clause of the Act of Congress of August 5th, 1882: "Such vessels . . . . to be constructed of steel, of domestic manufacture, having, as near as may be, a tensile strength of not less than sixty thousand pounds to the square inch, and a ductility in eight inches of not less than twenty-five per centum."

RULE III.—In every lot of twenty plates, test-pieces to be cut from two plates taken at random; two test-pieces being cut from each plate,—one in the direction of the rolling, and one at right angles to it, shaped according to the annexed sketch. These test-pieces shall in no case be annealed.

The test-pieces to be submitted to a direct tensile stress, until they break, and in a machine of approved character.

The initial stress to be as near the elastic limit as possible, which limit is to be carefully determined by the inspector in a special series of tests. The first load to be kept in continuous action for five minutes. Additional loads to be then added at intervals of time, as nearly as possible equal, and separated by half a minute; the loads to produce a strain of 5000 pounds per square inch of original section of the test-piece, until the stress is about 50,000 pounds per square inch of original section, when the additional loads should be in increments not exceeding 1000 pounds.

An observation to be made of the corresponding elongation measured upon the original length of eight inches.

Conditions of Acceptance.—In order to be accepted, the average of the four test-pieces must show an ultimate tensile strength of at least 60,000 pounds per square inch of original section, and a final elongation in eight inches of not less than 25 per cent.

Lots of material, which show a strength greater than 60,000 pounds per square inch, will be accepted, providing the ductility remains at least 23 per cent.

Cases of Failure.—If the average of these four test-pieces, numbered 1, 2, 3, 4 (called Test I.), fall below either of the required limits, the plates, from which pieces 1, 2, 3, 4 were cut, shall be rejected, and Test II. made, consisting of pieces 5 and 6, cut from a third plate. If the mean of the results of these two fall below either of the above limits, the entire lot shall be rejected. If it be successful, Test III., or the mean of pieces 7 and 8 cut from a fourth plate, shall decide.

If, in any of Tests I., II., III., any single piece shows a tensile strength less than 58,000 pounds, or a final elongation less than 21 per cent, the plate from which it was cut shall be rejected, and that test considered to have failed, regardless of its average.

RULE IV.—*Quenching Test.*—A test-piece shall be cut from *each* plate, angle or beam, and, after heating it to a cherry-red, plunged in water at a temperature of 82° F. Thus prepared, it must be possible to bend the pieces under a press or hammer, so that they shall be doubled round a curve, of which the diameter is not less than one and a half times the thickness of the plates tested, without presenting any trace of cracking.

These test-pieces must not have their sheared sides rounded off; the only treatment permitted being taking off the sharpness of the edges with a fine file.

RULE VII.—*Each* boiler-plate must be subjected to the same tests, and in the manner prescribed for ship-plates. The ductility in eight inches must not be less than 25 per cent., and the ultimate tensile strength must not be less than 57,000 pounds, and not more than 63,000 pounds, and the average, at least, 60,000 pounds.

The following diagrams represent, Fig. 1, the 8-inch and Fig. 2, the 1-inch test-piece. The tests were made on an improved 100,000 pound Riehlé hydraulic machine.

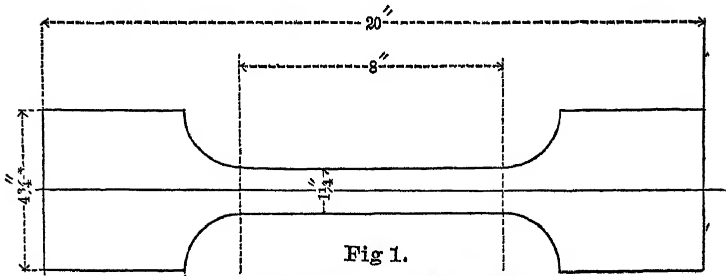


Fig 1.

*N.B.-Figures marked * may be altered to suit testing machine*

In the original specifications, it will be observed by reference to the above rules, that plates of only 58,000 pounds tensile strength might pass, provided the average of all the test-pieces was 60,000 pounds, or over; but, in the amended specifications we were not

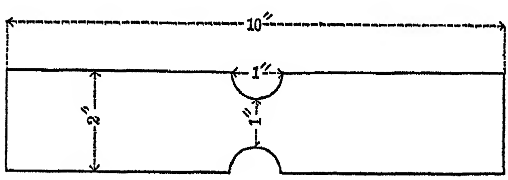


Fig 2.

granted even this little piece of grace, and, unless the average of the two test-pieces, selected from each heat, was 60,000 pounds or over, and 23 per cent. stretch or over (and in neither test to fall below 58,000 pounds, or 21 per cent.), the heat was rejected. In other words, to take a practical example, if two test-pieces from the same heat gave 59,900 pounds tensile strength, with the required elongation, the heat was rejected. If, however, one of those pieces gave 58,000 pounds, and the other 62,000 pounds, with other conditions remaining the same, the heat was accepted.

To give some idea of the manner in which the inspection was first conducted, I refer to heat 435 (inserted between 534 and 536) in the table. Here the tensile strength was 56,900, instead of 57,000 (for boiler-plate), with a splendid elongation of 28 per cent.; yet, notwithstanding this fact, the heat was rejected, and we were not allowed to roll that metal for the cruisers. This, also, in view of

the well-known fact that the difference of the $\frac{1}{100}$th of an inch in taking measurements of test-pieces makes a difference of 1200 pounds to the square inch in a half-inch section,—that is, a section from a plate half an inch thick; and further, that two pieces from the same plate, taken side by side, will frequently vary several thousand pounds. If we take heat 500, with dimensions 1 × .5, and change the .5 to .49, we get a tensile strength of 64,300 pounds, or 1300 pounds difference. Conversely, if the error should be the other way, .51 instead of .5, we would get a tensile strength of 61,800 pounds, or 1200 pounds difference. Of course, in plates less than half an inch in thickness, the difference is still greater.

We found no difficulty in getting the desired ductility or elongation, since all our best boiler-plate gives from 28 to 30 per cent. in an 8-inch section; but the trouble came in getting the tensile strength to run over 60,000 lbs., and maintaining at the same time the very high percentage of elongation required. This difficulty was finally overcome, and we were able to meet the specifications with gratifying regularity.

Heat 453 (see table) is inserted to show the character of steel we were making previous to our undertaking to make the cruiser-steel. The manganese, however, is a little below the average, which should be about 0.25 per cent. In other respects its characteristics are those of the best boiler-plate.

Out of the first 33 heats, from 464 to 496, we lost 14, or 42 per cent. Only four of these heats, however, could be called inferior; the remaining ten being, in my opinion, better material than that accepted. In the next 100 heats only 10 failed to pass the specifications. Nine of these were condemned on account of being too soft, only one (No. 525) for being too hard, *i.e.*, not giving the required stretch. It would have been possible to secure a still lower percentage of condemned heats; but we did not care to risk making metal like No. 525, and preferred to fail occasionally by making it too soft, since this metal, when rejected, we could use for the best flange and fire-box plate. In the last 47 heats only three failed to come up to the specifications. No. 602 we did not test, and No. 604 was lost.

The first hundred heats, from No. 464 to No. 563, in addition to the usual amount of pig iron, scrap, and shearings, contained charcoal-blooms and muck-bar (gradually increased amounts of muck-bar and a corresponding diminution of blooms, which were at first charged in equal amounts). Nos. 564 to 619 were all made from

muck-bar, with results equally if not more satisfactory than with blooms. Of the remaining heats, a few were made from all blooms, a few from all muck-bar, and the others from a mixture of the two.

The tests marked with an asterisk were made on pieces cut at right angles to the direction of rolling; the others with the grain, or in the direction of the rolling.

Let us now consider the indications here given as to the influence of carbon, manganese, phosphorus, and silicon on the physical qualities of the steel. The average amount of phosphorus is .039 per cent., and this, I think, will compare favorably with any other steel that has ever been made, taking the number of heats into consideration. The highest phosphorus is found in heats Nos. 551 and 552, where it is .075; and yet those heats give excellent results. Again, in Nos. 548 and 549, we find .069 phosphorus, with good results. Conversely, in heats Nos. 605 and 606, we find low phosphorus, .042 and .044 per cent. respectively, with results not so good; and still again, in heat No. 499, the phosphorus is only .031, with results not equal to those first mentioned. We are safe in assuming, therefore, so far as the above tests are concerned, that phosphorus up to the amount of .075 is not very injurious to the physical properties of soft steel. In all cases in this table where the results are not up to the standard the cause can be directly traced to something else besides phosphorus. In my opinion, phosphorus is not the terrible *bête noir* it has been considered; it has had to bear the burden of many sins wrongfully ascribed to it.

The average amount of carbon is .15, which I regard as being from .03 to .05 too high for the best boiler-plate. The influence of carbon is more certain and regular than that of phosphorus, although there appear to be a few exceptions to the rule that tensile strength increases with carbon. Heat No. 517 has .22 carbon, with 66,000 tensile strength, while heat No. 530, with .18 carbon, gives 70,000 tensile strength, with the same amount of manganese in both cases; and heat No. 532, with .17 carbon and less manganese than the others, gives a still higher tensile strength of 72,000. Again, in heat No. 566, we have .20 carbon and only 59,600 tensile strength, with a splendid elongation amounting in one case to nearly 31 per cent. These, however, are, I believe, the only exceptions of importance to the rule that tensile strength increases with the amount of carbon; and I will presently suggest an explanation that will account for nearly all the anomalous results.

The average amount of manganese is .38 per cent. Manganese

plays a part similar to carbon, only in a lower degree, and may have comparatively much wider limits of variation than carbon without altering the result. The highest manganese we find in heats Nos. 603 and 503, viz.: .73 per cent and .58 per cent. respectively; and in both cases comparatively high tensile strength and diminished elongation; the carbon in both cases being above the average. There are other cases, however, with manganese above the average, where neither the tensile strength nor the elongation is unduly affected. Heat No. 509 is an example, but it is low in carbon. In heat No. 515, with manganese the same as in No. 509, but with carbon a few points higher, the tensile strength is high again. The lowest manganese is .17 per cent. in heat No. 453, with the best results; and again, Nos. 538, 544, 557 and 567, showing .24, .27, .29 and .27 per cent. of manganese respectively, all give excellent results. The manganese, as we would naturally expect, increases or diminishes with the carbon, and the tensile strength in direct proportion to both.

Another point of interest to which I wish to call attention, is the variation of carbon before and after the addition of ferro-manganese. This variation ranges from .01 per cent in heat No. 487 to .10 in No. 617. Assuming that ferro-manganese contains about 5 per cent. of carbon, then the theoretical amount added would be, in a one per cent. change, just .05 per cent. It is easy to understand that the increase of carbon is sometimes less than .05 per cent. after the addition of the ferro-manganese, because there is always more or less opportunity for oxidation, but why it should ever be greater than .05 per cent. is not so easy to understand. I would suggest as an explanation of this abnormal increase of carbon, that a portion of the carbon, before the addition of ferro-manganese, was present as graphite, and that the ferro-manganese caused this graphitic carbon to combine.

The influence of silicon on steel has been but little studied. This has been due to the fact that it is generally present in such small quantities as to make it a question whether or not it has any influence on the physical qualities of the metal.

Silicon prevents carbon from combining with iron. This interesting fact, although known in a general way by those who have studied the chemistry of pig-iron, was altogether ignored or lost sight of in steel, until its importance was discovered by Col. Caron. Since then, it has been commented on in Mr. Ward's *Note on the*

*Behavior of Manganese to Carbon,** and in Mr. Alex. Pourcel's note on the same subject.†

Phosphorus, I believe, acts in a similar manner; for it is a well known fact that high phosphorus irons will not *chill*, that is, the carbon will not combine with the iron. These facts open up a new line of thought; and I am led to the conclusion that phosphorus and silicon in steel are not *hardeners*, as heretofore supposed, but are injurious, first, because they have a tendency to keep the carbon in the graphitic state; and second, because they act mechanically (as phosphide and silicide of iron, sometimes, perhaps, as phosphate and silicate of iron) like graphite, to separate the particles of the metal, or in other words, to destroy its continuity or homogeneity. In fact, when we come to think of it as a question of molecular physics, it is difficult to conceive how they could ever have been regarded as hardeners. I am led to this conclusion not only by the results that I have obtained, but also by a study of Dr. Dudley's chemical and physical tests of rails.‡ This is such an important point that I may be excused for citing a few examples from Dr. Dudley's tables.

No. 911 with .618 per cent. of carbon and 1.044 per cent. of manganese gives 69,000 tensile strength, while No. 906, with less than one-half the amounts of carbon and manganese (.308 per cent. and .462 per cent. respectively) gives the same tensile strength. Now there are only three hypotheses by which we can account for the tensile strength being the same, with such vastly different chemical compositions: we may suppose, first, that the carbon is not all combined; or, second, that the steel contains varying amounts of oxide of iron; or, third, that both these causes are combined. If the carbon in either of the above cases had been all combined (leaving out of the question, at present, oxide of iron), then it is evident that the tensile strength would not only have differed, but would have been much higher in both cases. No. 911 would have shown about 100,000 pounds, and No. 906 about 80,000 pounds. And if it should be found that the carbon *was* all combined, then the low tensile strength of No. 911 must be due to the presence of oxide of iron.

If the above conclusion be true, it follows as a corollary that wear is not so much a question of hardness or softness, as of homogeneity. At all events this theory will account for nearly all Dr. Dudley's anomalous results. It explains why rails from 80,000 to 90,000

* *Transactions*, vol. x., p. 268.

† *Transactions*, vol. xi., p. 197.

‡ *Transactions*, vol. ix., p. 320.

tensile strength, are good (see Dudley's tables, Nos. 885 and 917), and why softer rails, from 54,000 to 69,000, are bad (see same tables Nos. 903 and 923).

It confirms Dr. Dudley's general conclusions, though not for the same reasons. While on this subject, I may say that I agree with Mr. Pourcel, that a high manganese rail may show better wear than a low one, but not for the same reason as he gives. The manganese by removing oxide of iron, and counteracting the effect of silicon and phosphorus, in other words causing the carbon to combine, performs a valuable function in thus rendering the metal homogeneous; but if the same effect could be produced without any manganese being present, I maintain that the steel would be still better. Manganese, *per se*, is a hard, brittle metal, and there is no reason to suppose that when alloyed with iron its qualities change, and that it imparts only hardness without brittleness.

Unfortunately I have not been able to make any graphite or total carbon determinations except in heat No. 612, which I was led to examine more thoroughly chemically, on account of the phenomenal way it behaved in the furnace. It contains, besides the .16 per cent. of combined carbon, .15 per cent. of graphite carbon, and .014 per cent. silicon. Of course I do not mean to contend that .014 per cent. of silicon will account for .15 per cent. of graphite; but be that as it may, the graphite is there, and produces the effect we would naturally expect. With a tensile strength of about 63,000 pounds, we only get 23.5 per cent. of elongation; whereas, with the tensile strength as low as that, other things being equal, we ought to get about 28 per cent. elongation. The pig-iron used in this heat (about 15 per cent. of the total charge), was a very high-silicon No. 1 pig; and the test-piece, after the heat was melted and ready for the ferro-manganese, instead of being tough, was as brittle as if the carbon had been .5 per cent. or .6 per cent. It was kept in the furnace three hours longer than the usual time (about 6 hours), and doctored with iron-ore and blooms, and finally cast with the above results. In this case the determination of carbon by either the combustion or the colorimetric method alone, would not give the desired information.

The methods employed for chemical analysis were, for carbon, the color-test, dissolving a standard every time; for phosphorus, the molybdate method, weighing the yellow precipitate; for manganese, the modification of Ford's method, by dissolving in acid protosulphate of iron the binoxide precipitated from nitric acid solution

by chlorate of potash, and titrating with permanganate of potash. The latter method, when carefully worked, I regard as the most accurate method of determining manganese.

To return to the physical tests: the next point worthy of consideration, is the relation of reduction of area to tensile strength and elongation. Steel may give a high percentage of elongation, with a comparatively low percentage of reduction of area, like the second tests of Nos. 611 and 644; or it may give a low percentage of elongation, with a comparatively high percentage of reduction of area, like Nos. 466 and 490. But the material that I regard as being best adapted for boilers, is that in which both the elongation and the reduction of area are high; say, from 28 per cent. to 30 per cent. elongation, and from 56 per cent. to 60 per cent. reduction of area. The reduction of area should be, and generally is, in an 8-inch section, just double the elongation. When they are both low, the tensile strength is apt to be high, and the quality inferior.

It is to be regretted that we could not anneal the test-pieces without annealing the plates, as this would have removed all variations in the results, due to differences of mechanical treatment, and perhaps would have prevented anomalous results. So much has been written on the treatment of steel, that it would be out of place for me in this paper, to do more than mention in a general way that many of the failures which manufacturers experience with steel plates, are due to the improper manner in which they handle them. Moreover, it is certain that steel plates, after having been flanged and punched, ought to be annealed; for even if they do stand without cracking the severe handling which they receive, they go into the boiler in a state of strain or tension that is dangerous.

The 5th test of No. 464 has been inserted to show what different results can be obtained with the same metal under different treatment. This test was taken from a plate made for the centre-keelson of the "Dolphin." It was a difficult plate to make, being about 40 feet long, 5 feet wide, and nearly half an inch thick, and was finished at a black heat, giving results as shown in the table. When, however, a test-piece from the same plate was annealed, the trouble was immediately remedied, and the test gave 64,000 tensile strength and over 25 per cent. elongation.

Finally, I wish to call the attention of the Institute to what I consider the most important point developed by these tests, viz., the necessity of having some uniformity in the methods of making physical tests. When we read of a piece of metal having a tensile

strength of 60,000 lbs., and a ductility of 25 per cent., we should know just what these figures mean. With the present methods of testing, they may mean much or little. Let standard test-pieces be established and specifications be made, based on such standards. Moreover, unless the conditions under which the tests are made are precisely uniform, no two tests can be compared with each other; for not only do the size and shape of test-pieces affect the results, but also the time, manner of applying the loads, duration of stresses, etc., etc. I give below a few tests, showing the different results obtained under different conditions.

The first test shows the effect of different thicknesses of the same metal.

Dimensions.	Tensile Strength.	Elongation in 8 inches
.762 x .7 inch.	52,600 pounds.	30.8 per cent.
1.25 x .36 "	57,200 "	29.68 "

In this case, by diminishing the thickness of the plate from .7 to .36 inch, we increase the tensile strength 4600 lbs. These differences are still more marked and astonishing if we break test-pieces of different sections from 1 inch to 8 inches. Whether the loads be applied rapidly or slowly, also makes a difference.

Section.	Dimensions.	Tensile Strength.	Elongation.	
1 inch.	.624 x .602 inch.	75,000 pounds.		across grain.
8 "	.8 x .605 "	65,600 "	23.8 per cent.	across grain.
1 "	.633 x .591 "	73,500 "		with grain.
8 "	.8 x .588 "	65,800 "	22 8 per cent.	with grain.

The above tests were all carefully made on steel furnished for boiler-plate by a well-known manufacturer in this country. Again with our steel:

	Section.	Tensile Strength.	Red. of Area.	Elongation.
A.	1 inch.	67,300 pounds.	58 per cent.	34 per cent.
A.	8 "	58,000 "	65 " "	25 " "
B.	1 "	69,700 "	46 " "	31 " "
B.	8 "	57,000 "	58 " "	27 " "

Here we have a difference in the case of B of nearly 13,000 lbs. Besides the difference in section, however, the pieces of 1-inch section were all pulled fast; that is to say, no appreciable interval was allowed between the application of the loads as in the 8-inch sections. It would be easy to multiply such examples; but I think it must be evident from the above that the consumer might as well not make any specifications, unless he prescribes all the conditions of testing, viz., thickness of plate, size of test-piece, shape of test-piece, amount

of load, duration of stresses, etc. In view of these facts, and the time, trouble, and expense of making so many physical tests, I believe the day is not far distant when chemical specifications alone will be prescribed. Indeed, it is quite possible now to recognize good or bad steel by its chemical analysis: and if some one will only give us a method for determining oxide of iron, it could be done with certainty every time. Chemical methods are becoming more rapid and accurate every day. Combined carbon can now be determined in five minutes and manganese in one hour, and with a previous knowledge of the stock from which the steel is made, there is little more to be desired.

It gives me great pleasure to acknowledge the valuable services of my assistants, Mr. Josef Westesson, who made most of the chemical analyses, and Mr. Loudon Richards, who had charge of the physical tests.

NOTE.—From the following table several heats are omitted, having failed for various reasons. In the case of 535, ingots remaining on hand from an old heat, No. 435, were substituted, and this number is inserted in the place of 535 in the table in order to preserve the proper correspondence with the "Testing-machine Record" of the Chester Rolling Mills.

Heat No.	Dimensions of test piece.	Area	Area of least section after breaking.	Original length of minimum section measured between shoulders.	Length after breaking	Breaking strain.	Tensile strength per square inch	Reduction of cross-section or area	Ultimate elongation in 8 in	Carbon before addition of ferro-manganese	Carbon	Phosphorus.	Manganese.
	Inches.	Sq in.	Sq in.	Inches	In	lbs	lbs.	p. ct	p. ct.				
453	1 125 x 35	.3937	.12	8	10 186	20,870	53,010	69	27 1		10	036	17
464	1 12 x .59	.6628	.2962	8	10 156	43,350	65,405	55 3	26 95		.19	.039	37
464	936 x .703	6580	.3049	8	10 19	43,500	66,100	53 6	27.38				
464	.985 x 695	.6846	3115	8	10 09	47,200	68,940	54.5	26 12				
464	967 x 715	.6914	2934	8	10 017	45,250	65,300	57 7	25 21				
464	1.24 x 455	5642	.3056	8	9 58	40,000	70,900	45 8	19 7	rol	led	cold.	
465	1 245 x .482	60	2511	8	10 254	36,600	61,000	58	28 2				
*465	1 25 x .482	6025	3199	8	9 978	36,000	59,580	53.	24.74		13	035	.38
466	.96 x .586	5625	2935	8	9 934	41,300	73,300	47 8	24 2		20	.030	37
*466	1 127 x .442	.5149	27	8	9.63	36,000	69,916	57.2	20 37				
467	928 x .57	529	2412	8	9 895	36,390	68,790	54.	23 7				
*467	984 x 579	5697	.3125	8	10.206	39,330	69,000	47.	27.82				
468	1 02 x 285	2907	1417	8	9 675	19,160	65,910	48.	20.93				
469	975 x .448	.4368	196	8	10 12	27,500	62,900	55.	26 5				
*469	1 264 x .6	.7584	3656	8	10 026	46,500	61,313	51 7	25 32				
470	.921 x .569	5240	2501	8	10 383	34,100	65,000	52.	29 8				
*470	989 x .575	.5686	.2956	8	9 9	36,400	64,000	50.	23.7				
471	1 01 x .454	.4585	1891	8	10 161	26,000	56,600	58 7	27 01				
*471	1 25 x 595	.7437	3171	8	9 875	46,540	62,600	53.	23 44				
472	1. x 46	46	1925	8	10 17	27,700	60,130	58.	26 13				
*472	1. x 463	463	232	8	9.942	27,600	59,600	50	24 28				
473	1 3 x .438	.5694	2571	8	10 25	33,950	59,600	54 8	28 13				
*473	1 035 x 55	.5692	2142	8	10.262	33,700	59,200	62 5	28 15				
474	1 155 x 576	.6653	.2508	8	10.469	36,800	55,300	62.	30 86				
475	.985 x 488	.4806	1965	8	10.04	27,700	57,630	59 1	30				
*475	.985 x .484	.4767	1885	8	10 32	27,550	57,790	56 2	29				
476	.94 x .5	47	.165	8	10 255	24,900	53,000	64 8	28 25				
477	1 235 x 441	5446	.261	8	10 29	31,900	58,500	52.1	28 63				
*477	1 261 x 441	5561	.2594	8	10 31	32,150	57,800	53.1	28 88				
478	1. x 615	615	.255	8	10 408	34,200	55,600	58 5	30 1				
479	.909 x 529	.5284	206	8	10 138	29,300	55,400	61.	26 98				
480	1.028 x 56	5756	261	8	10.375	34,000	59,000	56 3	29.68				
*480	1 x .564	.564	.2968	8	10.289	32,400	57,400	47.3	28 61				
481	1 x .475	.475	2131	8	10.244	26,300	55,790	55.	28 05		.11		.36
482	1.266 x .495	6266	.3035	8	10.143	40,000	63,836	51 5	26.79	18	.20		.38
*482	1.266 x .504	.6380	.3633	8	9.68	41,000	64,500	43.	21.				
483	1 225 x 485	5941	.2455	8	10.208	32,800	55,200	58.7	27.60	.09	.11		.36
484	1.205 x 418	5036	.2728	8	9.882	35,800	71,000	45.8	23.52	.15	.21		.40
*484	1 254 x .44	.5517	.3451	8	9.688	39,100	79,860	37.4	21.1				
485	1 25 x .507	.6337	.252	8	10 272	35,000	55,200	60.2	28.4	.09	.11		.34
486	1 135 x 50	.5675	.2730	8	10.275	36,130	63,665	51.8	28.4	.10	.12		.37
*486	1.24 x .513	.6361	.3648	8	9 78	39,100	61,400	42 6	22.25				
487	1.19 x 575	6842	.2788	8	10 17	41,150	60,143	59.25	27 25	.14	.15		.37
*487	1.249 x .586	.7219	.3356	8	10 084	44,000	60,950	53.5	26.05				
488	1.25 x .525	.6562	.264	8	10.545	36,800	56,080	59 9	31.81	.10	14		.39
489	1 072 x .472	.5059	.2385	8	9 875	30,000	59,300	52.8	24.68	.09	.13		.40
*489	1.246 x .481	.5993	2557	8	10.025	35,300	59,280	57.9	25 31				
490	1.187 x .339	4028	.1842	8	9 66	29,600	73,500	54 2	20.75	.16	21		.56
491	1 264 x .408	.514	.2053	8	10.016	32,900	64,000	60.	25 2	.13	.17		.50
*491	1 262 x .411	.5186	2491	8	10.046	32,700	63,000	51.9	25 59				
492	1.256 x .292	.3677	1516	8	10.	23,650	64,310	57.	25.	.09	13		.49
*492	1 265 x .293	.3706	.1780	8	10 264	23,650	63,860	51.9	28 3				
493	1.26 x .509	.6413	.3521	8	9 983	44,000	68,600	45.	21 78	.14	16		.53
*493	1 254 x .361	.4527	.2055	8	10.025	30,000	66,200	54.6	25 31				
494	1.217 x .39	4746	2187	8	9.959	31,300	65,900	53 9	24.48	10	.16		.50
*494	1 25 x 387	4837	2269	8	10.029	31,900	65,900	53.	25 36				
495	1 25 x .342	.4275	1938	8	9.970	26,300	61,500	54.7	24.62	09	.13	.062	.49
*495	1 25 x .348	.4351	2229	8	10 045	26,000	59,700	46 4	25.6				
496	1 25 x 275	.3437	.1828	8	9 435	23,460	67,660	46.8	17 87	.11	.15	.016	.50
497	1 254 x 296	.3701	.1702	8	9.96	23,300	62,900	54.	24 5	.09	.13		.46
*497	1.25 x .315	.3937	.1896	8	9 854	25,300	64,700	49 3	23.1				
498	1. x .47	47	.2142	8	9 912	30,000	64,000	54.4	23.9	.12	.16	.058	.49
498	1. x .475	475	.2338	8	10.025	31,800	66,900	50.8	25.2				
499	1 25 x 285	.3562		8	10.	23,950	67,300	52.8	25.	.09	.15	.031	.50
499	1.25 x .298	.3725		8	9.945	25,300	67,900	53.4	24 31				
500	1. x .5	.5		8	10.256	31,500	63,000	55.2	28.2	.11	.15		49
500	1. x .5	.5		8	10 144	31,600	63,200	55.8	26.8				
501	1.23 x 327	4022		8	9 98	26,290	66,680	47 4	24.75	.11	.14		.56
501	1.2 x .321	3852		8	10.128	24,900	64,640	50.	26.6				
502	1 237 x .37	.4576		8	10 048	28,450	62,200	52.3	25 6	.11	.15		.50
502	1 237 x .37	.4576		8	10.048	29,100	63,500	52.	25 6				

Heat No.	Dimensions of test piece	Area	Area of least section after breaking	Original length of minimum section measured between shoulders.	Length after breaking	Breaking strain	Tensile strength per square inch	Reduction of cross-section or area	Ultimate elongation in 8 in.	Carbon before addition of ferro-manganese	Carbon	Phosphorus.	Manganese
	Inches.	Sq. in	Sq in	Inches	In	lbs	lbs	p ct	p ct				
503	1 25 x .432	.5400	2994	8	10 008	39,700	73,600	41 5	25 1	.15	17		.58
503	1. x 49	49	2599	8	9 955	34,150	70,300	49	24 41				
503	.98 x 455	.4459	2050	8	9 9	31,700	71,000	54	23 75				
503	1 x 455	455	2117	8	9 864	32,700	71,860	53 4	23 3				
503	1.25 x 43	.5375	2949	8	9 861	39,600	73,600	45.1	23 26				
504	.992 x .484	4801	2304	8	10 112	30,800	64,100	52.	26 4	09	.17		.45
504	1 007 x 484	4873		8	9 875	31,350	64,300	52.9	23 43				
505	1. x 458	.458	1845	8	10 333	28,000	61,800	59 2	29 1	09	.15		39
505	97 x 462	4481	2016	8	10 085	27,500	61,600	55.	26 06				
506	.975 x 485	.4728	1961	8	10 164	29,700	62,800	58 5	27	.08	.14		.43
506	975 x .485	4728	.1902	8	10 100	29,200	61,750	59 7	26.31				
507	1 167 x 433	.5053	2485	8	9 911	33,000	65,300	50 8	23.88	.10	.15		.54
507	1.212 x .425	.5278	2682	8	10 06	35,000	66,310	49 2	25 83				
508	1 25 x 472	.59	.3058	8	10 225	37,000	62,700	48.1	27 8	11	.14		49
508	1 25 x 478	5975	2765	8	10.062	37,400	62,400	53 7	25 77				
509	1 25 x 46	.575	261	8	10 275	35,400	61,560	54 6	28 13	.08	12		.53
509	1 25 x 456	57	2781	8	9 937	36,000	63,000	51 2	24.21				
510	1 25 x 463	5787	2579	8	9 965	35,700	61,960	55 4	24.6	.08	15		.47
510	1 245 x 465	5785	2566	8	10 165	36,000	62,100	55.6	27.6				
511	1 x 467	467	2277	8	9 97	28,800	61,600	51.2	24 63	.07	.15		.48
511	1. x 478	478	2156	8	10 284	29,000	60,700	54.9	28 55				
512	1 x 485	485	2205	8	10 08	31,300	64,580	54.5	26.	.13	16		.48
512	1. x .489	.489	228	8	9 848	31,500	64,400	58.1	23.1				
513	.99 x .461	.4593	.2041	8	10 120	28,450	61,000	55.4	26 5	09	.14		.47
513	.982 x 46	.4517	.1995	8	10 075	27,500	60,800	55 8	25 9				
514	.983 x 45	.4423	.1883	8	9 796	27,800	62,800	57 8	22 45	.12	.15		.40
514	.983 x .435	.4276	1969	8	9.960	27,150	63,900	53.9	24.5				
515	1.212 x .385	.4781	2405	8	9 975	32,600	68,100	49.6	24 7	.12	.16		.53
515	1 23 x .38	.4674	.2484	8	9.975	31,900	68,200	47.	24 7				
516	1.233 x 48	.5918	2555	8	10 115	37,400	63,000	56 8	26 43	.10	16		.43
516	1 225 x 475	5818	258	8	10 145	37,200	63,900	55 5	26 81				
517	1.25 x .455	.5687	2634	8	9 927	37,400	65,750	53.6	24.08	.17	.22		.43
517	1.243 x .441	.5481	2714	8	9 872	36,400	66,100	50.4	23 4				
518	1.251 x 404	5066	2312	8	10.	34,000	67,100	58.7	25	.15	.19		.43
518	1 25 x .404	.505	2320	8	10	33,900	67,100	51.	25.				
519	.961 x 44	.4212	21	8	10.133	27,200	64,100	50 5	26 6	.13	.18		.49
519	.972 x 435	.4228	.198	8	9 892	27,850	65,800	52 9	23 67				
520	.969 x 69	.6685	3368	8	9 885	41,850	62,600	49 4	23.6	.12	.15		46
520	.985 x .685	6747	3334	8	10 209	41,600	61,600	49.8	27 6				
521	.962 x .722	6945	.3307	8	10.16	44,250	63,700	52.3	27.	.11	.14		.44
521	.988 x 460	.4545	.1918	8	10.17	29,500	61,000	57.8	27.1				
522	.981 x .686	.6730	.2903	8	9 986	43,900	65,200	55 3	24.8	.12	16		.46
522	985 x 688	.6775	3588	8	9 82	46,200	68,200	47	22 75				
523	.995 x .707	.7034	.2979	8	10 116	43,750	62,200	57 6	26 45	.09	14		.38
523	997 x .711	7088	.3106	8	10.272	43,280	61,080	54.6	28 4				
524	.985 x .71	.6993	.3471	8	10.	42,900	61,300	50 3	26 25	10	.14		.39
524	988 x .71	.7015	.3118	8	10 161	42,800	61,000	55 5	27 01				
525	1 21 x .531	.6581		8	9.718	41,800	68,000		21 47	.12	.16		.46
525	1.25 x .527	.6587	3672	8	9 762	42,800	64,900	44 3	22.02				
526	.967 x .705	.6817	3299	8	9.84	41.000	60,120	51.6	23.	.08	14		.46
526	.963 x .698	.6721	3230	8	10.117	40,750	60,620	51.9	26.46				
527	.967 x 706	.6827	.3503	8	9.995	43,650	63,930	48 6	21 93	.12	.14		.41
527	.985 x .705	6944	.3431	8	9.855	43,500	62,640	50.5	23.18				
528	.997 x .708	7059	.3501	8	10.063	52,500	74,370	50 4	25.78	.15	.21		.46
528	.989 x .709	.7012	.36	8	9.825	52,400	74,700	48.6	22 81				
529	.983 x .700	.6881	.3272	8	10.018	43,000	62,480	51.	25.22	10	.16		.40
529	1. x .695	.695	3371	8	10 085	43,350	62,370	51.5	26 06				
530	.985 x .703	.6924	.343	8	9 9	48,000	69,300	50.	23 75	.18	.18		43
530	.98 x .700	.686	.3127	8	9 8	48,100	70,000	54 4	22.5				
531	.995 x .575	.5721	.3013	8	9.875	38,500	67,290	47.3	23.43	.12	.16		35
531	.998 x .577	.5728	.2815	8	10 136	37,000	64,200	51.1	26.7				
532	.978 x .554	.5418	.2874	8	9.875	38,950	71,900	46 9	23 43	.13	17		35
532	.985 x 555	.5466	.2893	8	9 785	37,850	69,240	48 5	23 37				
533	.975 x .832	.7912	.3630	8	10.10	47,700	60,260	54.	26 25	.11	.14		.30
533	.983 x 837	.8227	.3169	8	10 38	47,200	57,370	61 5	20.75				
534	.975 x .715	.6971	.2756	8	10.22	40,000	57,370	60 4	27.75	08	.12		.25
534	.974 x 719	.7003	.2893	8	10.323	40,050	57,180	58.6	29.04				
485	.963 x .712	.6856	.2550	8	10 225	39,000	56,900	62 2	27.81				
536	.95 x .693	.6583	2634	8	10 333	35,850	54,450	56.5	29.16	06	.11		.45
536	.865 x .70	.6055	.2408	8	10.25	32,550	53,750	58.5	28 12				
537	1 234 x .375	.4627	.1898	8	10.127	27,900	60,3 0	58.9	26.83	.09	.11		36

Heat No.	Dimensions of test piece.	Area	Area of least section after breaking	Original length of minimum section measured between shoulders	Length after breaking	Breaking strain.	Tensile strength per square inch.	Reduction of cross-section or area.	Ultimate elongation in 8 in	Carbon before addition of ferro-manganese	Carbon	Phosphorus.	Manganese
	Inches	Sq in.	Sq in	Inches.	In	lbs	lbs	p. ct	p ct				
537	1 262 x 368	.4644	2061	8	10 145	28,100	60,720	55 6	26 81				
538	1 277 x 498	6359	.2378	8	10 5	35,900	56,400	62 6	31 25	05	11		.21
538	1 035 x 492	5092	1950	8	10 291	28,600	56,100	61.7	28 63				
539	1.216 x 492	5982	.2407	8	10 2	33,600	56,160	58.	27 5	.07	14		.33
539	1 036 x 480	4972	.2044	8	10 10	29,350	59,030	58 8	26 2				
539	1 036 x 475	4930	2027	8	10 175	29,260	59,300	58.9	27 1				
540	1.25 x 36	.45	.225	8	10 085	28,000	62,200	50.	25 81	.05	.10		.31
540	1 312 x .356	4671	.2330	8	9 875	28,850	61,900	49 9	23 43				
541	1.210 x 344	4162	.1877	8	9 96	25,200	60,250	54 9	24 5	.04	.13		.29
541	1 25 x 345	4312	.1870	8	10 05	26,000	60,296	56 6	25 62				
542	1 210 x 375	4537	.2231	8	10 15	27,450	60,500	50.8	26 87	.05	.14		36
542	1 25 x .370	.4625	.1991	8	10 332	27,900	60,320	50 5	29 15				
543	1.205 x .410	4940	.1961	8	10 457	28,260	57,200	60	30 7	05	15		.31
543	1.255 x 416	.5220	2142	8	10 30	29,850	57,180	58 9	28 75				
544	1 210 x 463	.5602	.2422	8	10 40	30,800	54,800	56 7	30	.06	.14		27
545	1.261 x 335	4224	.1833	8	10 267	23,100	54,600	56	28 33	06	.13	061	32
546	1 271 x .398	5058	.2129	8	10 187	29,500	58,300	57.9	27 3	.09	14	057	.29
546	1 263 x 4	.5052	2378	8	10 172	29,500	58,300	52 9	27 15				
547	1 256 x 432	5425	.2111	8	10 512	31,000	57,100	61.	31 4	.06	.15	.058	30
547	1 262 x 428	.5101	.2013	8	10 425	31,200	57,800	62.	30 3				
548	1 258 x 35	4403	.1871	8	10 405	25,800	58,600	57 5	30	10	16	069	.27
548	1 243 x 357	4437	.1744	8	10 288	26,500	59,700	60 6	28 6				
549	1 204 x 445	.5257	.2320	8	10 20	33,300	63,300	55 8	27 5	.08	19	069	31
549	1 082 x 443	.4571	.1952	8	10 23	28,950	63,300	57 2	27 93				
550	1 260 x 325	4095	.1952	8	10 245	26,700	65,200	50.	28 06	05	15	.064	.10
550	1 255 x 34	.4267	.1918	8	10 310	26,700	62,570	55.	28 87				
551	1 250 x 432	5400	.2119	8	10 50	29,650	54,900	60 7	31 25	04	.11	.075	.28
552	1 148 x 415	.4764	.1881	8	10 358	27,550	57,820	56 3	29 47	04	.13	.075	.30
552	1 165 x 410	4776	.2098	8	10 225	27,550	57,680	56 2	27 8				
553	1.160 x 370	.4292	.1581	8	10 45	22,400	52,190	62 6	30 6	.01	11	.051	.25
553	1 115 x 373	4158	.1548	8	10 36	21,700	52,180	62 8	29 5				
554	1 125 x .415	4668	2131	8	10 29	28,100	60,200	54 3	28 6	.06	16	.062	.42
554	.995 x 417	4119	.1709	8	10 208	25,150	60,600	58 7	27 6				
555	1.064 x 419	4458	1966	8	10 325	26,200	58,800	55 9	29 06	01	.14	.061	28
555	1 115 x 392	.4370	1860	8	10 265	25,900	59,200	57 2	28 2				
556	750 x .672	5040	2371	8	10 385	30,150	59,800	52 9	29 8	.06	.15	.043	.30
556	773 x .71	.5488	2202	8	10.275	31,500	57,400	59 8	28 13				
557	762 x .7	5334	2227	8	10.465	28,100	52,600	52	30 8	.06	.14	.050	.29
557	1.25 x 36	45	2117	8	10 375	25,750	57,220	53 7	29 68				
557	1.312 x .37	4854	.1980	8	10 06	27,650	56,960	57	25 75				
558	1 25 x 375	.4688	2612	8	9.875	30,600	65,200	44 3	23 43	.06	.15	.046	38
558	1.26 x 385	.4851	.2327	8	9 915	29,700	61,000	52	23 9				
559	1.03 x .346	3563	1435	8	10 36	20,500	57,500	59 7	29 5	.07	.16	.052	.27
559	1 015 x 347	.3522	.1396	8	10 25	20,500	28,200	60.	28 1				
560	1 023 x 324	3314	1384	8	10 325	20,500	56,400	58 5	29 06	.06	.11	.072	.30
561	1.035 x 485	.5019	2195	8	10 03	30,500	60,760	50.	25 37	.08	.16	.039	.39
561	1 025 x .482	494	.2283	8	10.15	29,750	60,220	53 9	26.87				
562	.975 x 47	.4582	.1881	8	10 25	26,400	57,600	58.9	28 10	.09	.16	.050	.28
562	1 005 x 475	.4773	.2006	8	10 40	27,650	57,900	58	30				
563	.988 x 462	.4564	.1859	8	10.375	26,150	57,300	59.	29 7	08	.11	014	.33
563	1. x 46	.46	1965	8	10 31	26,300	58,000	57 3	28 9				
564	1 310 x 348	.4559	2005	8	10.066	26,850	59,100	56	25 8	.08	.16	.037	40
564	1.312 x 353	.4631	.1778	8	9 975	26,800	57,900	61 1	24 7				
565	975 x 538	5245	.2244	8	10 197	31,350	59,790	57 2	27 46	.12	.18	.038	.39
565	1.005 x .54	5427	.2401	8	10.343	33,800	61,300	55 7	29 3				
566	.985 x 53	522	.2145	8	10.219	30,500	58,430	58 9	27 73	.11	.20	.039	41
566	975 x 525	.5118	.2168	8	10 468	30,500	59,600	57 4	30 8				
567	1.017 x 53	539	.2167	8	10.25	31,450	58,350	60 9	28 10	.09	.17	.05	.27
567	1.025 x 537	5504	2146	8	10.468	31,600	57,400	61.	30 8				
568	1.028 x .5	.5140	2289	8	10 25	32,450	63,100	55.4	28 1	.11	.17	.014	42
568	1.023 x 495	.5064	.2376	8	10.188	30,750	60,700	53.	27 34				
569	1 027 x .368	.3779	.2423	8	9.969	24,900	65,800	41	24 6	.11	17	.042	41
569	1 025 x 350	3587	.1937	8	9.719	23,900	66,600	46.	21 485				
570	1 016 x 380	.3859	.1704	8	10 375	24,700	64,500	55 8	29 68	.11	.17		42
570	1.022 x 365	.3730	.1810	8	10.125	23,600	63,200	51.4	26 56				
571	1 028 x 594	6111	3433	8	9 72	38,200	62,500	43 8	21.5	.11	.16	.047	.41
571	1 028 x .595	6116	3257	8	10.09	38,700	63,300	46.7	26 175				
572	1.034 x 565	.5842	.2772	8	10.47	33,500	57,340	52 5	30 86	.10	.15	.053	.37
572	1.03 x 565	.5819	.2645	8	10 28	34,100	57,800	51	28 5				
573	1.035 x 7	7245	4517	8	10 06	41,400	61,200	37	25 78	.09	.17	.039	.29
573	1 048 x .7	.7335	.3253	8	10.22	42,250	57,600	55 6	27.1				

Heat No	Dimensions of test piece.	Area	Area of least section after breaking	Original length of minimum section measured between shoulders	Length after breaking	Breaking strain	Tensile strength per square inch	Reduction of cross-section of area.	Ultimate elongation in 8 in.	Carbon before addition of ferro-manganese	Carbon	Phosphorus.	Manganese.
	Inches	Sq in	Sq in	Inches	In.	lbs.	lbs	p ct	p ct				
574	1 023 x 69	7058	3045	8	10 312	41,100	58,200	56 8	28 9	08	14	038	.35
574	1 05 x .712	7476	2938	8	10 281	41,900	56,000	60.	28 5				
675	815 x 572	.4661	1981	8	10 064	28,000	60,000	57.3	25 8	07	13	042	30
575	840 x 565	.4746	1799	8	10 187	27,850	58,700	61.	27 3				
576	99 x 565	5591	2292	8	10 313	34,500	61,700	59	28 9	08	14	.048	.36
576	975 x 565	5509	2368	8	10	33,600	60,900	58 8	25				
577	96 x 56	5280	2063	8	10 313	50,300	57,400	60	28 9	.08	14	033	39
577	.98 x 55	.539	2010	8	10 56	30,550	56,700	62.	32.				
578	.98 x 552	5405	2112	8	10 56	31,300	57,860	60 9	32		14	050	40
578	854 x 555	4739	1776	8	10 28	27,450	57,900	62	28.5				
579	788 x 548	.4318	1806	8	10 187	25,700	59,500	58 1	27 3		15	047	37
579	8 x 545	4.360	1830	8	10 25	26,500	60,700	59	28 1				
580	1 008 x 71	.7157	2992	8	10 031	43,000	60,000	56 8	25.31	12	.17	042	41
580	.755 x 709	5353	2175	8	9 97	32,350	60,430	59 3	24 63				
581	1.065 x 706	7518	3219	8	10 531	43,100	57,300	56 6	31 64	.07	14	047	33
581	1 151 x 71	8193	.3419	8	10 25	48,250	59,800	57 9	28.1				
582	1.115 x 575	6411	3097	8	10 56	37,150	57,900	51 6	32	.08	15	.048	.36
582	1 08 x 57	6156	2888	8	10 375	35,600	57,800	51 4	29 68				
583	1 036 x 546	5556	2211	8	10 188	31,850	57,300	60.	27 34	.07	15	.055	32
583	1 068 x 543	5799	2485	8	10 594	32,400	55,910	57.1	32 42				
585	1.252 x 468	.5859	2651	8	10 316	38,000	64,800	54.5	28.9				
585	1.252 x 465	5831	2693	8	9 9	39,300	67,300	53 8	23 7				
586	1 25 x 475	.5937	2889	8	10 05	35,100	59,120	51 3	25 62	.08	13	.052	.33
586	1.245 x .47	5851	2575	8	20 127	34 800	58,100	55.9	26 6				
587	1.218 x 475	5932	2562	8	10 31	34,650	58,400	56 8	28.9	.08	.14	.016	.33
587	1 24 x 47	5828	3138	8	10 152	37,000	63,400	44.2	26 9				
588	1 242 x 495	6148	.225	8	10 072	38,700	62,900	60	25.9	.12	.16	.048	.43
588	1 252 x 503	.6297	2912	8	9 953	38,000	60,300	53 7	21.4				
589	1 31 x 475	.6222	3021	8	9.91	39,900	64,400	51.	23 9	.12	16	.046	49
589	1 3 x 471	6123	.2895	8	10 05	40,000	65,300	52 7	25 6				
590	1 228 x 48	.5894	2676	8	10 121	36,150	61,300	54 6	26 5	.08	.14	.052	39
590	1 255 x 488	.6027	3078	8	9 904	35,750	59,300	48 9	23 8				
591	1 225 x 488	5978	3063	8	10 065	39,450	65,900	48 9	25 81			.059	46
591	1 258 x .49	.6161	3111	8	10 088	39,150	63,400	49 4	26 1				
592	1.236 x 518	6402	3438	8	10.05	42,150	65,800	46 3	25 6	.12	.14	045	41
592	1.22 x 519	6332	3884	8	10	41,400	65,380	38 6	25.				
593	1 28 x .505	6464	3121	8	10 104	41,150	63,600	47.	26.3	.10	19	.054	44
593	1.279 x .503	.6433	.3139	8	10.	39,500	61,400	50	25				
594	1.274 x .494	6194	3204	8	10.109	38,150	61,500	48 2	26 36	.09	15	052	42
594	1.275 x .490	.6247	.3067	8	10 128	39,750	63,600	50.	26 6				
595	1.26 x .448	.5644	.2441	8	10.25	52,750	57,800	56 7	28 1	.08	.13	.016	.36
595	1.26 x 445	.5607	.2651	8	10.110	53,500	59,700	52.7	26 4				
596	1 215 x .487	.5917	.3122	8	9.97	36,650	61,900	40.7	21 6	.12	16	037	42
596	1.19 x .480	.5722	.3015	8	10 067	37,250	65,000	46	25 8				
597	1.22 x .471	.5716	.2964	8	9.915	37,500	65,200	48 4	23.93	.12	17	.056	36
597	1.225 x .472	.5782	.2816	8	9.878	36,900	63,800	51.	23 5				
598	1 227 x .505	.6196	.2608	8	10 158	36,100	58,200	57 8	26 9	07	12	.054	.34
598	1.24 x .498	6175	.2621	8	10 275	33,950	54,900	57 5	28.4				
600	1 254 x .502	.6295	.3096	8	9 76	41,250	65,300	50 8	22.	.12	18	.060	40
600	1.23 x 501	.6162	3255	8	9 775	41,100	66,600	47.	22.2				
601	1.222 x .485	5926	3195	8	10.	38,200	64,400	46.	25	13	18	.048	37
601	1 225 x .48	.588	.3147	8	10 045	38,300	65,100	46 4	25 5				
603	1 252 x .492	6160	.3895	8	9.66	43.200	70,000	37.	20 8		.19	.056	73
603	1 26 x .497	.6262	3791	8	9 775	43,500	69,400	39 3	22 2				
605	1.12 x 44	.4928	3066	8	9.89	31,100	63,700	38	23 6	.11	17	044	50
605	1.25 x .438	.5475	.3240	8	10 02	35,900	65,500	40 8	25 3				
606	1.175 x .509	598	.3589	8	9.575	38,900	65,000	40.	19 7	09	14	.012	47
607	.769 x .706	.5429	.2971	8	9 92	36,150	66,500	45.2	24	.09	.15	018	29
607	1 245 x .704	.8765	.3595	8	10.075	55,200	63,000	47 4	25.7				
608	1.217 x .512	.6231	.2985	8	10.033	36,700	58,900	52.	25.4		16	.013	27
608	1 2 x .506	6072	.2882	8	10.	37,250	61.200	52.	25.				
609	1.21 x 509	.6159	.3311	8	9.875	40,250	65,000	46.2	23 43	09	.15	.052	.29
610	1.195 x 473	.5652	.2720	8	10.375	37,300	65,900	51.8	29 67	.08	15	062	.38
610	1 243 x .476	.5917	303	8	9.96	37,800	64,000	51 2	24.5				
611	1.179 x .473	.5577	.3027	8	9 841	36,100	61,700	45.7	23 01	.09	17	.047	38
611	1 245 x .469	.5839	3096	8	10.25	38,100	65,000	47.	28 1				
612	1.231 x .486	.5983	.3276	8	9,938	37,000	61,800	45 2	24.22		16	.065	.32
612	1.249 x 484	.6045	.2855	8	9 855	39,500	54,900	52 7	23 2				
613	1 245 x .455	.5665	3007	8	10.	35,250	62,200	47.	25	.09	16	.061	.39
613	1.211 x .458	5697	3092	8	9.8	36,300	63,700	44	22.5				
614	1.238 x .46	.5695	.2866	8	10 312	35,000	61,400	49.6	25 39	.08	.16	051	39

Heat No.	Dimensions of test piece.	Area	Area of least section after breaking	Original length of minimum section measured between shoulders	Length after breaking	Breaking strain.	Tensile strength per square inch	Reduction of cross-section of area.	Ultimate elongation in 8 in	Carbon before addition of ferro-manganese	Carbon	Phosphorus	Manganese
	Inches	Sq in	Sq in	Inches	In	lbs	lbs	p ct	p ct.				
614	1 242 x 458	5688	.2946	8	10 38	34,500	60,600	48 2	29 7				
615	1 24 x 47	5828	2861	8	10 185	36,100	61,900	50 9	27 3	.10	17	051	11
615	1 248 x 473	5903	3031	8	10.	37,100	62,800	48 6	25				
616	1 257 x 5	6285	2882	8	10 317	38,750	61,600	54	28 9	.09	16	057	11
616	1 271 x 5	6355	3091	8	9 915	30,750	62,500	51	21 3				
617	1 255 x 51	64	3034	8	10,06	43,400	67,800	47 4	25 75	10	20	066	39
617	1 270 x 512	6502	3192	8	10 06	43,650	67,100	46 3	25 75				
618	1 27 x 513	6515	3718	8	9 84	41,850	64,000	42 9	23		15	.057	45
618	1 25 x 513	6412	3864	8	9 88	45,000	70,000	39 7	23 5				
619	1 26 x 548	6905	380	8	10 225	43,850	63,500	42	27 8		16	059	36
619	1 266 x 552	6988	4610	8	9 955	43,750	62,600	31	24 3				
620	1.252 x .497	6222	3208	8	9 848	44,900	72,300	48 1	23 1				
620	1 255 x 5	6275	3686	8	9 880	46,500	71,000	41	23 5				
621	1 248 x 545	6802	3285	8	10 025	42,400	62,300	51 8	25 3		15	048	36
621	1 245 x 51	6723	3321	8	9 955	42,500	63,200	50 6	24 1				
622	1 25 x 539	6737	3474	8	10 085	42,500	63,000	49 3	26 06		17	.051	17
622	1.25 x 540	675	3494	8	10 166	43,000	63,700	48 2	27 07				
623	1 244 x 48	5971	3188	8	10 103	38,000	63,600	46 6	26.29		15	060	.43
623	1 248 x 487	6077	3168	8	10 178	38,600	63,000	47 8	27 2				
624	1 248 x 487	6078	3226	8	10.150	41,000	67,400	46 9	26.87		.15	.052	41
624	1 25 x 485	6062	.3077	8	10 252	42,000	69,000	49	28				
625	1 25 x 465	5812	2835	8	10 08	38,750	66,200	51	26.		16	.061	38
625	1 27 x 468	5916	3178	8	10 02	39 500	66,400	46 5	25 2				
626	1 245 x 465	5789	.3012	8	9 905	40,300	69,400	47 4	28 8		.19	.045	33
626	1 26 x 466	5871	3174	8	9 92	39,500	67,300	45.9	24				
627	1 25 x 51	6375	3707	8	9 915	45,600	71,500	41 8	33 93		19	050	41
627	1 25 x 512	640	36	8	10 12	46,000	71,900	43 3	26.5				
628	1 25 x 498	62 5	2949	8	10 225	35,250	56,600	52 6	27 81		12	053	36
628	1 25 x 490	6125	3063	8	10	36,500	59,500	50	25.				
630	1 43 x .525	6526	3456	8	9 85	39,250	60,100	47	23 1		13	018	.49
630	985 x 525	517	.245	8	9 880	32,300	62,800	52 5	23 5				
631	1 195 x 491	5867	3204	8	9 885	37,500	63,900	45 3	23 56		.17	051	.44
631	1 255 x 490	6150	36	8	9 868	38,900	63,200	41 4	23.35				
632	1 192 x 472	5626	2958	8	9 895	35,350	63,600	47	23 7		.14	.052	.34
632	1.196 x 477	5701	2907	8	10.28	36,000	63,000	49	28 5				
633	1 2 x .496	5952	.2689	8	10 025	35,400	59,400	51 8	25 3		.15	.047	.41
633	1 214 x 494	5997	2774	8	10 085	34,700	57,800	53 7	26.				
634	1.209 x .5	6045	.2992	8	10 06	37,250	61,600	50 5	25 7		.16	.051	.45
634	1.256 x 5	628	3240	8	9 95	38,750	61,700	48 1	24 3				
635	1 212 x 487	5902	.2814	8	10 11	33,300	56,760	52 3	26.7		.13	.056	.36
635	1 2 x 488	5856	.2797	8	10 055	33,800	57,700	52 2	25 7				
636	1.198 x 480	5750	2838	8	9 95	34,150	59,300	50 6	24.37		.15	.051	39
636	1.2 x .485	582	3000	8	9.805	34,600	59,400	48 1	22 57				
637	1.198 x 482	.5771	2520	8	10 24	30,900	53,500	56 3	28		.13	049	.31
637	1 198 x 480	5750	.2860	8	10 006	30,900	52,000	50.2	27 5				
638	1 252 x .53	6636	.3591	8	9 925	43,600	65,700	45 8	24 06		11	049	.39
638	1.257 x 531	6674	4075	8	9.882	44,500	66,600	38 8	23 5				
639	1.245 x 523	.6511	3139	8	10 05	37,300	57,280	51 7	25 6		.13	.05	.36
639	1.25 x .523	.6537	.3201	8	10.24	37,700	57,600	51 3	28				
640	1 255 x .49	.6149	3132	8	10 235	36,000	58,400	49	27 8		.13	.049	.30
640	1 26 x 49	.6174	.2975	8	10 268	36,850	59,600	51 8	28 3				
641	1.284 x .49	.6291	2932	8	10 01	39,500	62,700	46 6	25.		.14	.054	.42
641	1.270 x .5	.6350	.3319	8	10 075	40,500	63,700	47.7	25 9				
642	1 260 x .493	6212	.2924	8	10.168	35,500	57,100	52 9	27		12	.017	21
642	1 285 x 49	6296	.2768	8	10 212	35,700	56,700	56	27 6				
643	1.297 x 485	.6290	3052	8	10 388	38,500	61,000	51.5	29 8		15	.040	.30
643	1 270 x 485	.616	2892	8	10.175	37,700	61,200	53.	27.				
644	1 254 x 498	6245	.3095	8	9.875	37,700	60,300	50.4	23 4		15	.055	.41
644	1 272 x .5	.6350	3305	8	10,38	39,700	60,900	48	29 7				
645	1 235 x 504	6224	3053	8	10,25	36,500	58,600	50 7	28 1		13	.061	.33
645	1 232 x 505	6221	3273	8	10 21	35,900	57,700	47.3	27.6				
646	1.241 x 497	.6167	.3141	8	10.186	37,000	60,000	49.	27.3		.15	050	.33
646	1 245 x 5	6225	.3293	8	10 005	36,500	58,600	47.	25				
647	1 240 x 454	.5629	2998	8	10 046	33,300	59,100	46 7	25.5		.12	.018	.38
647	1 215 x 454	.5652	2668	8	10 163	33,200	58,600	52.8	27.				

THE LAW OF THE APEX.

BY R. W. RAYMOND, NEW YORK CITY.

APPENDIX.

SINCE the foregoing paper (see p. 387) was printed, I have received the decision of Judge William E. Church, of the first District Court of Dakotah, in the case of *Michael Duggan et al.* v. *John H. and Frank J. Davey* (Silva Terra—Sitting Bull case), published in full in the *Black Hills Weekly Pioneer* of August 9th, 1884. The journal mentioned gives also several interlocutory decisions rendered in earlier stages of the case; but I shall quote here only so much of the final decision as bears upon the construction of the Revised Statutes concerning the apex, the end-lines, and the extra-lateral mining right, together with a sufficient statement of the facts of the case to explain the scope of the decision.

"This is an action in equity, brought in the first instance to restrain a threatened trespass by the defendants upon certain mining property in the possession of the plaintiffs, known as the 'Silver Terra' claim; the allegation being that the defendants were about to enter, through underground workings, the ground of the plaintiffs, and remove therefrom valuable bodies of silver ore.

"The answer of the defendants, admitting the acts constituting the alleged threatened trespass, further averred that they had, in fact, at the time complained of, reached and passed, in their underground workings, through and beyond the vertical side-line of the Silver Terra claim, and thereupon justified the acts complained of, and claimed the right to pursue their workings into and through the Silver Terra ground, by virtue of their alleged proprietorship of a vein, lode, or ledge of rock in place, bearing silver, having its top or apex within the lines of a certain other mining claim called the 'Sitting Bull,' of which they claim to be the owners, which vein, lode, or ledge extended in a continuous body of mineral-bearing rock from such top or apex to the ground in controversy, and constituted the body of ore in dispute; and that it was in the pursuit of this vein, lode, or ledge in its downward course that they had passed beyond the vertical side-lines of the Sitting Bull claim, and for some hundreds of feet beyond, into the ground in controversy

"Subsequently, a supplemental complaint was filed, setting up the entry into plaintiffs' ground by the defendants, and their claim of right to do so, and asking further relief by a decree restraining the assertion of such claim, and quieting the title of plaintiffs.

"The case was tried before the court without a jury. . . . .

"Custer hill, upon which these claims are located, is situated in the village of Galena, in Bare Butte mining district, in this county. The village lies at the base of the western slope of the hill, which presents a lateral face from south to north

(taken along the line of the outcrop hereafter mentioned) of 1300 or 1400 feet—of course at the base it is somewhat wider. At its northern extremity it turns to the east; and its northern slope presents a lateral face, from west to east, of upwards of 3000 feet at least Along its base, and following it in this turn, in the direction indicated, is a small stream called Bare Butte Creek. These slopes are quite steep, and extend from base to summit, about 1200 to 1300 feet. The whole country is hilly and broken; and this hill is only one of a series of similar elevations, with which it is more or less directly connected. Northwardly, across Bare Butte valley or gulch, which is there, perhaps, 500 feet or more in width, is another hill, known in this case as the Florence hill, whose southern slope extends laterally, from west to east, nearly parallel with Custer hill.

"Beginning now at or near the southern extremity of the western slope of Custer hill, at a point perhaps half-way or more up the slope, there is found an outcropping layer or stratum of a reddish quartzite or metamorphic sandstone, several feet in thickness (upwards of 10 feet, at least), overlaid by a body or stratum of limestone or dolomitic shale, of a thickness not definitely ascertained, but certainly extending several feet above the quartzite . . . . This is the furthest point northwardly [southwardly? R. W. R] or westwardly to which attention has been given in the case.

"From this point the croppings may be readily traced, in several places by high, reef-like ledges, jutting out boldly from the face of the hill, along the western face of [to? R. W R] its northern extremity. The general bearing of this line of cropping in the direction indicated is given by Mr Dickerman, one of the defendants' witnesses, as N. 11 degrees W., the distance as 1243 feet, and the angle of inclination upwards from south to north as 3 degrees 26 minutes. Mr. White, a witness for plaintiffs, gives the distance as 1300 feet, and the angle of inclination as somewhat less than that stated. At the northern extremity of the hill, this line of outcrop of quartzite with overlying limestone or dolomite turns and extends along the northern slope with a downward inclination, thus gradually nearing the base of the hill, until, at a distance of something over 2500 feet (not established by the testimony) it disappears beneath the bed of the creek. . . . .

"Along the whole line of this outcrop as thus described, locations of mining claims appear to have been made, which I note here, as they have been referred to in the testimony, mainly for convenience of description and reference.

"First on the south is the War Eagle location, north of that the Savage, then, on the same face of the hill, the Custer. I believe another location called the Highland Chief, embraces some part of this line, but have no certain reference to it. On the northern slope are, first the Neptune, then the Sitting Bull, and then the McClellan—all located in an easterly and westerly direction, end to end, along this line of outcrop already described extending across the northerly face of the hill.

"More specifically with reference to the Sitting Bull, that location is situated about midway—east and west—of the northerly face of the hill, and extends, from the point of discovery, about 690 feet in a direction S. 74° 30′ W. (reversely N. 74° 30′ E.), and from the same point about the same distance N. 89° 30′ E. The end-lines are parallel, having a bearing of S. 35° E. The claim is thus about 1380 feet long, and is about 300 feet in width. Throughout this length, the line of outcrop described is wholly within the side-lines of the location, and passes through the end-lines very nearly at their middle points.

"Adjoining the Sitting Bull on the south, and passing up the hill in the order named, are the Tiger Tail, Surplus, Fraction, and Silver Terra locations, all laid substantially parallel with the Sitting Bull. The Tiger Tail is owned or claimed by the defendants; the others, by the plaintiffs, or some of them. Adjoining the

Tiger Tail and Surplus on the west, and the Sitting Bull on the north, is another claim of the plaintiffs called the Richmond. For the Silver Terra and Sitting Bull claims the plaintiffs and defendants respectively hold patents of the United States

"As already stated, the ledge within the Sitting Bull location has been exposed by numerous excavations, and drifts have been run in various directions in the quartzite from all of which more or less valuable silver ore has from time to time been extracted.

" . . . . I must, therefore, find this body of quartzite to be a vein, lode, or ledge of rock in place, bearing silver, within the meaning of the statute.

"Secondly. Is the top or apex of this vein or lode within the lines of the Sitting Bull location?

"The definition of the top or apex of a vein usually given, is 'the end or edge of a vein nearest the surface' And to this definition the defendants insist we must adhere with absolute, literal, and exclusive strictness, so that whenever, under any circumstances, an edge of a vein can be found at any surface, regardless of all other circumstances, that is to be considered as the top or apex of the vein. The extent to which this view was carried by the defendants, and I must confess, its logical results, were exhibited by Professor Dickerman, their engineer, who, replying to an inquiry as to what would be the apex of a vein cropping out at an angle of one degree from the vertical, on a perpendicular hillside, and cropping out also at a right angle with that along the level summit of the hill, stated that, in his opinion, the whole line of that outcrop from the bottom clear over the hill as far as it extended, would be the apex of the vein.

"Some other witnesses had a similar opinion

"The definition given is, no doubt, correct under most circumstances, but, like many other definitions, is found to lack fulness and accuracy in special cases; and I do not think important questions of law are to be determined by a slavish adherence to this letter of an arbitrary definition. It is, indeed, difficult to see how any serious question could have arisen as to the practical meaning of the terms top or apex, but it seems, in fact, to have become somewhat clouded. I apprehend that if any intelligent person were asked to point out the top or apex of a house, a spire, a tree, or a hill, he would have no difficulty in doing so, and I do not see why the same common-sense should not be applied to a vein or lode Statutory words are to receive their ordinary interpretation, except where shown to have a special meaning· and as I think the testimony shows that these terms were unknown to miners in their application to veins, before the statute, the ordinary rule would seem to apply to them.

"Justice Goddard, a jurist of experience in mining law, in his charge to the jury in the case of the *Iron Silver* v. *The Louisville*, defines top or apex as the highest or terminal point of a vein 'where it approaches nearest the surface of the earth, and where it is broken on its edges so as to appear to be the beginning or end of the vein.'

"Chief Justice Beatty, of Nevada, who is mentioned in the report of the Public Lands commission of 1879–80, as 'one of the ablest jurists who has administered the mining laws,' in his letter to that commission says, after defining dip and course or strike: 'The top or apex of any part of a vein is found by following the line of its dip up to the highest point at which vein-matter exists in the fissure. According to this definition, the top or apex of a vein is the highest part of a vein along its entire course. If the vein is supposed to be divided into sections by vertical planes, at right angles to strike, the top or apex of each section is the highest part of the vein between the planes that bound that section; but if the dividing planes are not vertical, or not at right angles to a vein which departs at all from a perpendicular

in its downward course, then the highest part of the vein between such planes will not be the top nor apex of the section which they include.' (Report of Public Lands Commission, page 399.)

"I am aware that in several adjudged cases, top or apex and outcrop have been treated as synonymous, but never, so far as I am aware, with reference to a case presenting the same features as the present.

"The word apex ordinarily designates a point, and, so considered, the apex of a vein is the summit, the highest point in the vein in the ascent along the line of its dip or downward course, and beyond which the vein extends no further; so that it is the end, or, reversely, the beginning of the vein

"The word top, while including apex, may also include a succession of points, that is, a line; so that by the top of a vein would be meant the line connecting a succession of such highest points or apices, thus forming an edge.

"I have spoken of 'the dip or downward course' of the vein, treating these words as synonymous, and so I think they must be regarded. Dip and depth are of the same origin—dip is the direction or inclination towards the depth; and it is 'throughout their depths' that veins may be followed, and this is surely their downward course.

"Mr. Riotte gives us a different definition. He says: 'Starting any line upon the apex of the vein, and running down upon the vein parallel to the end-lines' (of the location) 'the inclination that line has is the downward course of the vein.' And when asked: 'So that the direction of the end-lines of a mining location absolutely fixes the direction of the downward course of the vein?' he replies: 'As far as it interests the man who has located that claim.'

"Elsewhere he says, that in his view of the law, end-lines of locations are, as he expresses it, 'swingable,' so that when the locator determines the direction of his ore-chutes, he may swing his end-lines parallel to them so as to take them in throughout their depth

"A very little reflection will show that if this be the law, a locator, instead of being limited to fifteen hundred feet along the vein, could readily place his end-lines at such an angle as practically to control nearly three thousand feet of the vein.

"With all proper respect for this gentleman's opinion, I cannot accept his views upon this subject at all. I think it clear that the law intended these lines to be laid substantially at right angles to the general course or strike of the vein—since in no other way could the locator be limited to a given length along the ledge.

"This seems to have been the view taken of the law by the three learned judges who sat in the Richmond-Eureka case. It is true that they there hold that the provisions of the law of 1872, requiring parallel end-lines, may be regarded as merely directory, so that a failure to so lay them would not invalidate the location; but I think the whole force of the observations of the court upon this point lies in their assumption that it makes no difference how the miner may choose to locate his end-lines, since the law limits his right to that section of the lode or ledge carved out by vertical planes, drawn through the extreme points or ends of his line of location, at right angles with a line representing the general course or strike of the lode. (See pp. 360–363 of Copp's U. S. M. L., second edition.)

"In this same case, on appeal to the Supreme Court of the United States (13 Otto, p. 844), the fact is noted that the 'zone,' as it is called, dips at right angles to its course or strike, and that the extension downwards of the compromise-line, which was coincident with the end-lines of the adjacent claims, followed the dip of the zone.

"I have been led into some digression from the strict line of my argument. .

"Bearing in mind the descriptions heretofore given of the two lines of outcrop on Custer hill, if we might suppose that the outcrop along the northerly face were nearly vertical, I do not see how it could be seriously contended that such outcrop, under the circumstances, constituted the top or apex of this stratum of quartzite. Such a conclusion could only be reached, as it seems to me, by shutting one's eyes to every feature of the case, except the one fact that there was an edge at or near the surface, which was, therefore, the top or apex of the vein.

"This I cannot do without such a violation of the ordinary use of words and, with all the respect and deference which I feel for the opinions of the learned counsel for the defence, I must say, without such a transgression of the dictates of a sound common-sense view of the situation as, in my judgment, the statute does not contemplate. Nor can I see that there would be any difference whatever in principle were this outcrop to be found at an angle of 45 degrees, or, as it is, at an angle of about 8 degrees from the horizontal. I am compelled, therefore, to hold that this outcrop, found in the Sitting Bull location, is not the top or apex of this vein, lode, or ledge, and that such top or apex is not within that location. I must regard that outcrop as merely an exposure of the edge of the vein on the line of its dip.

"But thirdly. If this is not the top or apex of the vein, then neither is it its longitudinal course.

"That by the use of the term 'along the vein,' the statute requires a location to be made along its longitudinal course or strike, I shall not stop to argue. Such again was the opinion of the court in the Eureka-Richmond case.

"But by the term 'strike,' in this connection, I do not mean the technical true strike of the engineer, the line which would be cut by a horizontal plane. Such a requirement would be in many cases impracticable.

"The Supreme Court of the United States has said in the Flagstaff case (*Mining Company* v. *Tarbet*, 8 Otto, 463), that 'the most practicable rule is to regard the course of the vein as that which is indicated by surface outcrop or surface explorations and workings'—and I have no disposition, as I should not be at liberty, to disregard the doctrine of that case, so far as it is applicable to the circumstances.

"In that case, a line of outcrop ran up a hill nearly in a westerly direction. A level line, run somewhere beneath the surface, showed the strike to be north 50 degrees west. The line of the Titus location was not far from midway between these two; and the court held, as against the Flagstaff, which was laid across these lines, that the location of the Titus was a good one, using the language above quoted. There, moreover, the dip of the vein was northeastward, and no such question arose as that involved in this case.

"In view of the principles already laid down, I think that the longitudinal course of this zone of quartzite is indicated by the croppings on the west face of the hill, and not by those on the northerly slope.

"After what has been said, it would seem unnecessary to consider whether this vein so far departs from a perpendicular in its course downward as to extend outside the vertically extended side-lines of defendants' location, and through the intervening ground to the ground in controversy—such could not be the case, consistently with the facts already ascertained.

"It may be conceded, as indeed, a mathematical conclusion from the facts, that by extending drifts from the Sitting Bull location throughout its vertically extended south side-line, in any direction upon the vein east of south, a downward inclination would be found; and that such is the fact with regard to the main working tunnel, which extends to the ground in controversy; but clearly this is not what the statute

contemplates; and if I am right in my other conclusions, probably this proposition would not be contested. . . .

"The decree must be that the plaintiffs are entitled to the relief demanded

"This disposes of the case for the present; but I feel bound to express my acknowledgment of the courtesy of counsel throughout the whole of this long and weary trial, both to me and to their adversaries. The importance of the interests involved, and the fact that this is the first case of the kind which I have been called upon to try, have led me to give many hours of my best thought and study to the determination of its questions, as I endeavored to give patient attention to its hearing. I am not conscious of having evaded any of its responsibilities, but have endeavored to so state the facts and my conclusions thereon, as to present the case in the best practicable form for the review which I hope may be made.

"I am fully aware of the importance of this determation to the defendants. This case affords another exemplification of the unfortunate results attendant upon the purpose of the government to dispose of ore-bodies as things distinct from the soil. The present laws are a hot-bed of litigation, and fruitful source of error.

"I could wish that this case had fallen into abler and more experienced hands than mine, but the duty has fallen upon me, and I have discharged it to the best of my ability."

If Judge Church had had long experience in mining cases, it is quite likely that he would have decided this question differently; but in that case he might really have contributed less to its final solution. The matter is surrounded with doubt; and it is no small advantage to the mining industry that it should be presented for the ultimate decision of the Supreme Court in a clear, thorough, and conscientious opinion like the foregoing, although that opinion seems to contravene the general present usage of miners, the letter of the Supreme Court decision in the Flagstaff case, and the letter of the statute.

This case may be better understood by reference to Fig. 3, in the foregoing paper, which is here reproduced for convenience. Assuming the right-hand side of the figure to be north, and the lower line *e e* of the claim *E* to represent the ridge of Custer hill, we have the outcrop *s x t y* running along the western slope, turning at *g*, extending along the northern slope through *z*, crossing the gulch and appearing again at *w* in Florence hill. Of course the directions and proportions are not exactly those of the actual case, since the figure is a purely imaginary one. But it was drawn to exhibit just such *conditions* as those described by the court. The plaintiffs in the case do not claim that their lines embrace the outcrop. They are situated as would be the owner of a location of which the point *u* is the centre, but in which the outcrop *t* is not included. At least, they do not plead the possession of any apex, but rest on their rights, as surface-owners, to all minerals beneath their surface, ex-

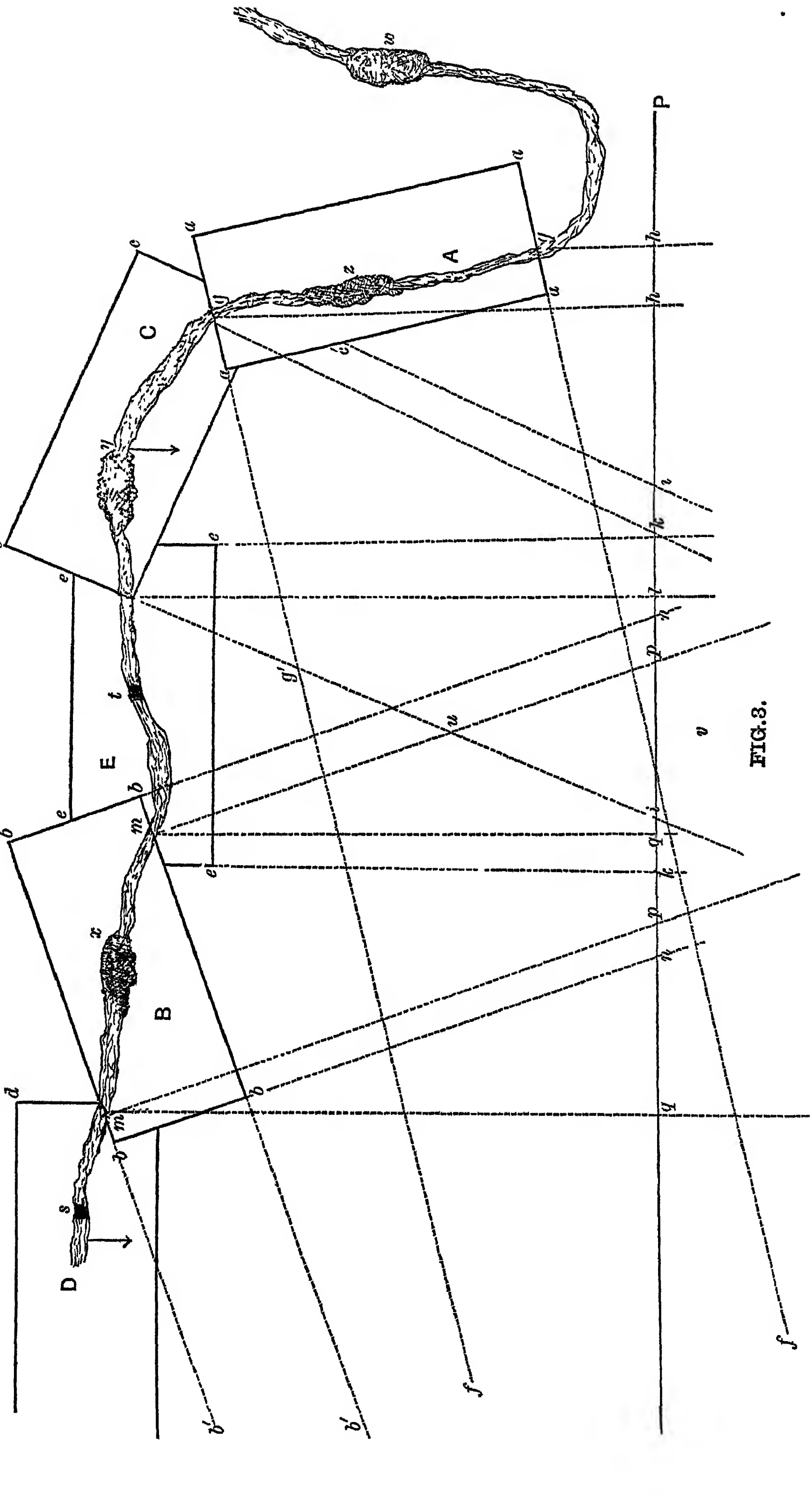


FIG.3.

cept such as may be included in lodes of which other locators possess the "top or apex." The court holds, very properly, that the burden of proof is upon any one who pretends to the right to enter the plaintiffs' ground. The mere exhibition of the patent or location-record, and proof of the surface-lines, makes a complete case for the plaintiffs, unless the defendants can affirmatively prove that in entering the plaintiffs' ground, they are following on its downward course a lode of which the apex is within their own ground.

The defendants occupy the position of the locator A in the figure. For the purposes of this decision, we may assume that they have the prior title. (There was conflicting testimony on this point; but the court passed it by, as not affecting the result under the final ruling.) They have, beyond dispute, the outcrop *gzg;* and they claim the right to follow the vein indefinitely between the lines *aaf*, *aaf*, and hence into, and through, the location including *u*.

The court decides that *gzg* is an undoubted outcrop, but not the top or apex; that *gg* is not the longitudinal course of the vein; that *af* is not the direction of its downward course; and, by implication, that the extra-lateral rights of the defendants are bounded by *gh*, *gh*. This is the case in a nutshell.

In my paper, I have stated both sides of the question with sufficient clearness, and do not purpose to reopen its discussion here. The weak point in Judge Church's decision seems to be a certain indefiniteness. He says he does not mean by the longitudinal course or strike "the technical true strike;" and he does not mean the course as shown on the surface. The truth is, that unless one or the other of these directions is adopted, there can be no guide at all to the locator. I infer that the court thinks the true strike should be sought, and that a rough approximation to it would be acceptable, and would not be deemed open to later corrections. The vagueness of this rule is evident. Moreover, the difficulty of making a location under the rule would be very great. It must be remembered that the Land Office holds the locator to his lines as once surveyed and fixed, and will allow no change of them which affects the rights of other parties. Now, under the ruling just quoted, how could A in Figure 3 make a valid location, being, as we have assumed, the first-comer on the hill, and having discovered only the exposed outcrop? According to mining-customs and the intention of the law (to say nothing of its letter) this first discoverer of a valuable mineral vein should have the right to a full claim upon it. The fact that he has discovered it in a steep place, instead of a level place, ought not to prevent him from acquiring and enjoying that

right. Nor should the law say to him: "Well done, enterprising prospector; you have found a lode hitherto unknown. Now work it underground, or discover it again in other places, and trace it until you know its true course, at least approximately; and *then* you may make a location on it, the end-lines of which, being drawn across the true, or nearly true, course, shall be your boundaries." He ought not to be bound to know, or to find out before location, the course of the vein outside of the claim he proposes to lay upon it; and while it is true that (except in the rare case of a perfectly vertical vein) the surface-outcrop, not being level, cannot show the true course, yet that negative fact helps him little.

But we will suppose that A, Fig. 3, makes his location after having discovered the outcrops at x, and y, and after having divined (for he could not well have proved at this early stage of operation) that x, y and z are all outcrops of one lode, and that its course is in the general direction xy. Nevertheless, for some reason, say because the ore exposed at z is richer than elsewhere, he desires to include that part of the lode in his claim. Under this ruling, he might put one end-line at lower g, with the direction gh. But where could he put the other? If he should draw it through the point c on the vein, with the direction cl, then he would have on the true course of the vein the length lh (the h nearest P); but his claim on the surface following the outcrop, would be nearly or quite twice as long; and the chances that the Land Office would admit such a location, or public sentiment would tolerate it, would be very small. The Revised Statutes, it will be remembered (section 2320), declare that a mining-claim "may equal, but shall not exceed, 1500 feet in length along the vein or lode," but also, that it "shall be governed as to length along the vein or lode by the customs, regulations, and laws in force at the date of their location." Now, I think there is no doubt that the customs of miners, now as heretofore, have limited the length of the claim by the surface-measurement, so that, if 1000 or 1500 feet were the customary length, no pretext would be permitted to justify a claim longer than that by surface-measurement. The consequent difficulty of A, in the case supposed, might be further described, but is, I trust, plain enough.

Another point in the decision seems to require comment. The court criticises the statement of Mr. Riotte, one of the expert witnesses, who has said that, in his view of the law, end-lines of locations are "swingable," so that when the locator determines the direction of his ore-shoots he may swing his end-lines parallel to them so as

o take them in throughout their depth. If this be a correct repre-entation of Mr. Riotte's view, that view is undoubtedly erroneous. A locator cannot swing or move his lines after once fixing them, if he existing rights of others would be affected by the change. But the proposition that he may originally locate them (or change them by re-survey, if the existing rights of others are not affected thereby) so that they will include the supposed downward course of the ore-shoots, is a different one, and not so certainly erroneous. Whether right or not, it is and has been a common practice.

Again, this decision seems to ignore the peculiar form of the grant of the extra-lateral right in the Revised Statutes. This I have already pointed out in my paper. The law first gives to the locator, broadly and sweepingly, all the lodes of which his claim includes the top or apex, and it is after this comprehensive grant that the limiting proviso occurs, restricting such ownership of the outside parts of such lodes to the portions included between the extended end-lines. The language is not easily capable of any construction that does not make one pair of end-lines the boundaries for the extra-lateral right on *all* lodes the top or apex of which is within the claim. It does not explicitly require that these end-lines should cross the true course of the lode at right angles. And the attempt to make it mean this involves a difficulty which may be best stated by a supposition. Suppose the location contains the apexes of two lodes, one crossing the end-lines at right angles, and the other crossing the same end-lines with maximum obliquity. What, under this decision, are the boundaries of the extra-lateral right on the latter?

Let us now consider more closely the manner in which this decision deals with the utterance of the Supreme Court in the Flagstaff case. On page 30 of my paper the words of the Supreme Court are quoted. It there appears that "*the principal difficulty in the case* arises from the fact that the surface is not level, but rises up a mountain," so that the strike of the vein which is really northwest, is made to appear on the surface as west, the dip being northeasterly. And in another quotation, on page 48, the court distinctly says, "As the law stands, we think that the right to follow the dip of the vein is bounded by the end-lines of the claim properly so-called; *which lines are those which are crosswise of the general course of the vein on the surface.*" On page 30, the court goes on to say that perhaps the law is imperfect in this regard; "perhaps the true course of a vein should correspond with its strike, or the line of a level run through it; but this can rarely be ascertained until considerable work has

been done, and after claims and locations have become fixed. The most practical rule is to regard the course of the vein as that which is indicated by surface-outcrop, or surface-exploration and workings. It is on this line that claims will naturally be laid, *whatever be the character of the surface, whether level or inclined.*"

Judge Church quotes part of this passage, disclaims any intention of disregarding it, and declares that the Flagstaff case did not involve the question now before him. It is true that the Flagstaff decision settled chiefly the point that the side-lines, if they cross the vein on the surface, become the end-lines, and limit the extra-lateral right; but in coming at this point, we have the word of the Supreme Court that the difference between surface-course and true course constituted *the principal difficulty in the case.* This difference amounted to about 45 degrees; in the case before the Dakotah court, the corresponding difference appears to have been nearly 90 degrees. The difference between these differences does not seem to involve any principle. And the declarations of the court, above quoted, seem to me to cover the Sitting Bull case. For the court says in the same decision (see page 48 of my paper) that in its opinion, "the right to follow the dip outside of the side-lines, is based on the hypothesis that the direction of these lines corresponds substantially with the course of the lode or vein at its apex on or near the surface;" and this, taken in connection with the declaration that the course on the surface may not be the true course, and the fact that in the case at bar, it was not the true course within some 45 degrees, constitutes a strong statement, which Judge Church's brief treatment does not fully meet.

His decision coincides in part with that suggested on page 52 of my paper. But the objections there raised to it, which appeared to me insurmountable, have not been removed by this more recent construction of the law. If the Supreme Court will take Judge Church's view, well and good. We shall know where we stand, at least; but there will be a great unsettling of titles. For against this ruling United States patents afford no protection. Its full logical consequences would require the rectification of innumerable underground boundaries, heretofore determined by end-lines which do not cross at right-angles the true courses of lodes. In many instances, the ownership of valuable *bonanzas* would be changed by such a rectification. To return for illustration to Fig. 3, if the true end-boundaries of the extra-lateral right of A are *gh*, *gh*, then the boundary of C's rights (at the left end of his claim) must be *cl* instead of *ci;* and if

the triangle *lci* contains a *bonanza*, E will get it instead of C, though C was on the ground first, and laid out his location before E had been heard of.

It would be going too far, however, to assert that this principle could not be practically applied. Aside from the difficulty of dealing with existing rights, it appears to be practicable that the mineral surveyor should be required in laying out the surface-lines of a location, to see that the end-lines cross at approximately right-angles the horizontal course of the lode, *provided*, that his determination and location of such lines be final, and not subject to later rectification. If the horizontal course of the lode throughout the location is not straight, then the necessary parallelism of the end-lines must be secured by assuming an average course, or by drawing a horizontal line through the two ends of the claim on the lode, and assuming that to be its course. Or other claims on the vein, if such exist, or other exposures of it, if such can be traced, might be taken into account; and the general course of the lode, as far as it is known, might be adopted, irrespective of local variations, as the line across which the end-boundaries must be laid at right angles. The side-lines, however, must run parallel with the lode at the surface; and the discoverer of an outcrop on a hillside would generally be put at disadvantage, because he could not get a surface-claim conforming to the law which would give him its full length on the horizontal course of the lode. Considering the circumstance that the larger number of outcrops discovered are not level, but inclined, and are first found on hillsides, where denudation has usually brought them within reach of human discovery, this objection is a serious one. The system could be enforced; but it would not be popular, and its success would be doubtful. Perhaps it would diminish litigation over mining rights; but to take rights away, in order that people may not fight about them, is a remedy not calculated to console the litigants.

The matter is again summed up in the sentences of Judge Church's decision, in which I heartily concur: "This case affords another exemplification of the unfortunate results attendant upon the purpose of the government to dispose of ore-bodies as things distinct from the soil. The present laws are a hot-bed of litigation, and fruitful source of error." He might have added, that this "purpose" of the government has its origin and continuance in the desire of the mining communities themselves. If they would favor a change, it could easily be secured.

INDEX.

[NOTE. In this Index, authors' names are printed in small capitals, and the titles of papers in italics. Casual references, giving little or no information about the subject referred to, are indicated by inclosing the page-numbers in brackets. The distinction between such references and those not so marked is not always sharply definable. A bracketed number opposite the name of a paper refers to the first mention of the paper, *i e.*, to the record of its presentation. Where the name of a paper is followed by a bracketed number only, it is indicated that the paper, though read by title, has not been printed in the *Transactions*. Often, where the title of a paper, as furnished to the *Transactions*, differs from the title as originally presented, the paper has been indexed under both. This disagreement of titles is due to the fact that the Proceedings are printed before the papers, and that authors frequently change their titles after the Proceedings have been printed. But under the author's name in the Index one or the other only of the titles of such papers has been employed.]

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